Analysis of the current state of water-resource management in the UK using Social Network Analysis and Agent-Based Modelling: a case study in the Wear Catchment, County Durham

SMITH, VICTORIA

Analysis of the Current State of Water-Resource Management in the UK Using Social Network Analysis and Agent-Based Modelling: a Case Study in the Wear Catchment, County Durham

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Abstract

Since the introduction of the Water Framework Directive in 2000, there has been a drive towards managing water resources at the catchment-scale in the UK. The rationale for this approach is driven by intentions of localising environmental improvement, involving a wide range of stakeholders working in collaboration to identify water issues and potential actions to address them. However, despite this recognition, and drive towards collaborative working, there has been little focus on how the stakeholders actually come together in water-resource management, for example: the role stakeholders play; what skills, expertise, and resources they contribute; and, how decisions are made in the collaboration. More specifically, there is an opportunity to conduct analysis and build understanding of the rules of collaboration behaviour, attitudes, activities and evolution directions. The overall aim of this research was to analyse the current state of water-resource management in the UK, focusing on cross-boundary interactions between governmental and non-governmental actors, specifically in the Wear Catchment, County Durham. To achieve this aim, a multi-method approach was utilised, including social network analysis and agent-based modelling, exploring the position and role of individual actors in the network, and how changes made to the network structure of stakeholders, could affect inter- and intra-group collaborations. Ultimately, by analysing the current state of collaboration in water-resource management, this research contributes to the wider understanding of progress made in terms of the management of water resources in the UK, including the strengths and potential flaws of the approach.

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I dedicate my PhD to my Grandad Eric.

I'll never stop aiming high!

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Chapter 1 – Introduction

The Catchment Based Approach (CaBA) for Integrated Water Resource Management (IRWM) in the UK is at a crossroads. While progress has been made in encouraging stakeholder involvement from all levels, there are still significant issues regarding understanding of the roles that the stakeholders play in the management of water resources, specifically, how the stakeholders interact and work together in managing water issues. With multi-actor natural resource governance arrangements there is a need to evaluate in more detail how changes in governance are being implemented within the water-management systems in practice, and how they are effective, or not as the case may be. An important framing for evaluation of current management practices is complexity, referring specifically to the components and relationships within the complex system of water-resource management, in this case, the network structure, and functions within the system. This thesis will address these issues using the Wear Catchment as a case study, using an innovative approach to investigate the roles and interactions of the stakeholders with social network analysis (SNA), the analysis of interviews, and agent-based modelling (ABM).

With recent changes in the governance of water, the UK provides an opportune location in which an assessment of the current state of water-resource management can be investigated. Owing to the locality of the Wear Catchment relative to Durham University, and the existence of links with multiple actors in the catchment, the Wear is an ideal place in the UK to base this study. By gathering knowledge on the current state of water-resource management in the Wear Catchment, it will help build a picture of working practices in the catchment, (and current ways of working), which can be used to inform discussions on progress and problem-solving between the multiple stakeholders. In a broader-context, knowledge can also be used to contribute to evaluations of the CaBA approach, and also to reflect on the wider theme of collaborative working at the catchment-scale.

To investigate the state of collaborative water-resource management there is a need to employ multiple modes of analysis to break down the complexity of the system of management and changing patterns of governance involving multiple stakeholders. Three methods that will be brought together in this research are SNA, interview analysis, and ABM, which in the context of investigating interactive behaviour in water-resource

management, there has been little application of these methods together. Using SNA, interview analysis, and ABM together to investigate the roles played by stakeholders, provides more than an ethnographic approach, instead allowing us to map out, model and visualise the complexity of human interactions. The approaches, perspectives and processes which will be applied in this research are as follows:

1. A systems approach will be used to form the basis of the analysis of the water-resource management activities, including interactions, between stakeholders in the Wear Catchment. It will provide a holistic high-level overview of the management operations within the catchment.
2. A network perspective will be used to understand and underpin the social complexity between stakeholders working in the Wear Catchment.
3. A qualitative analysis approach will be employed using interview data, to inform understanding of the functioning of the social network system, and to allow knowledge of the stakeholders to inform understandings of the complexity and everyday operation of water-resource management within the Wear Catchment. Qualitative analysis will compliment understanding and analysis of the stakeholder network and understanding of the system dynamics.
4. ABM will be used to allow exploration of the complex system through the running and subsequent analysis of simulations (Axelrod, 1997), focusing specifically on the interactions between stakeholders working in the Wear Catchment. ABM can be used as a tool for exploring the possible outcomes of behaviour changes, for example, decision-making in the context of managing water issues.

The remainder of this chapter introduces further the topic of research, giving background on the study area, providing detail on its physical characteristics and water issues. An evaluation of the current state of addressing and managing water issues is then given, starting with an overview of approaches to the governance of water. Focus then moves to the international level regarding IWRM, before focusing specifically on the UK regarding collaborative water-resource management, and the CaBA. Linking back to the Wear Catchment, detail is given on the CaBA in the context of the Wear Catchment, and how it links into a current water-resource management in the Wear. At the end of the chapter, the aim of the research is stated, along with the research objectives, which will be addressed to achieve the aim.

1.1. Wear Catchment

England and Wales are divided into ten River Basin Districts (RBDs), and 100 catchment[1] areas. The River Wear Catchment (just over 1,080 km^2) is in the Northumbrian River Basin District in the north-east of England (Figure 1.1) (Our River Wear, 2012). Rising in the North Pennines many small streams drain from the hills between Killhope Law and Burnhope Seat, forming the headwaters of the River Wear, around 650 m AOD (National Rivers Authority, 1995; Our River Wear, 2012). The River Wear begins at the confluence of the Burnhope and Killhope Burns at Wearhead (Figure 1.1). The high energy, rocky upland river flows east/south through Weardale, before gradually widening and deepening, meandering through the richer, flatter lowlands in the east of County Durham (Our River Wear, 2012). The lower part of the river flows through the urban areas of Bishop Auckland, Durham and Chester-le-Street. From Durham to Chester-le-Street, the river changes direction several times, flowing south-west past the medieval site of Finchale Priory, before heading eastwards through Chester-le-Street draining the more urban, lowland centres, flowing through the Lambton Estate where the river becomes tidal and navigable, allowing for the passing of vessels (Our River Wear, 2012). The river eventually discharges into the North Sea at Wearmouth in Sunderland (Figure 1.1). The total length of the river from Wearhead to Wearmouth is 97 km. Major tributaries of the River Wear include Rookhope Burn, Bollihope Burn and Waskerley Beck, draining the North Pennine moorland via Bedburn Beck flowing through Hamsterley Forest; and the rivers Gaunless, Browney and Deerness in the middle reaches, draining more urban and lowland areas (National Rivers Authority, 1995).

The Lower River Wear area (489 km^2), towards the east of the catchment, contains 25 waterbodies running through urban, agricultural and former mining areas. The area has a strategic location, with three major transport routes crossing it: the A1(M), A19 and the East Coast Mainline railway (National Rivers Authority, 1995; Our River Wear, 2012). The economy is predominantly driven by manufacturing, engineering, transport and warehousing, and the public sector (Our River Wear, 2012). The main area of economic activity is Sunderland, alongside other main towns and centres including Durham City and Chester-le-Street (Figure 1.1).

[1] Catchment – The area of land drained by a river.

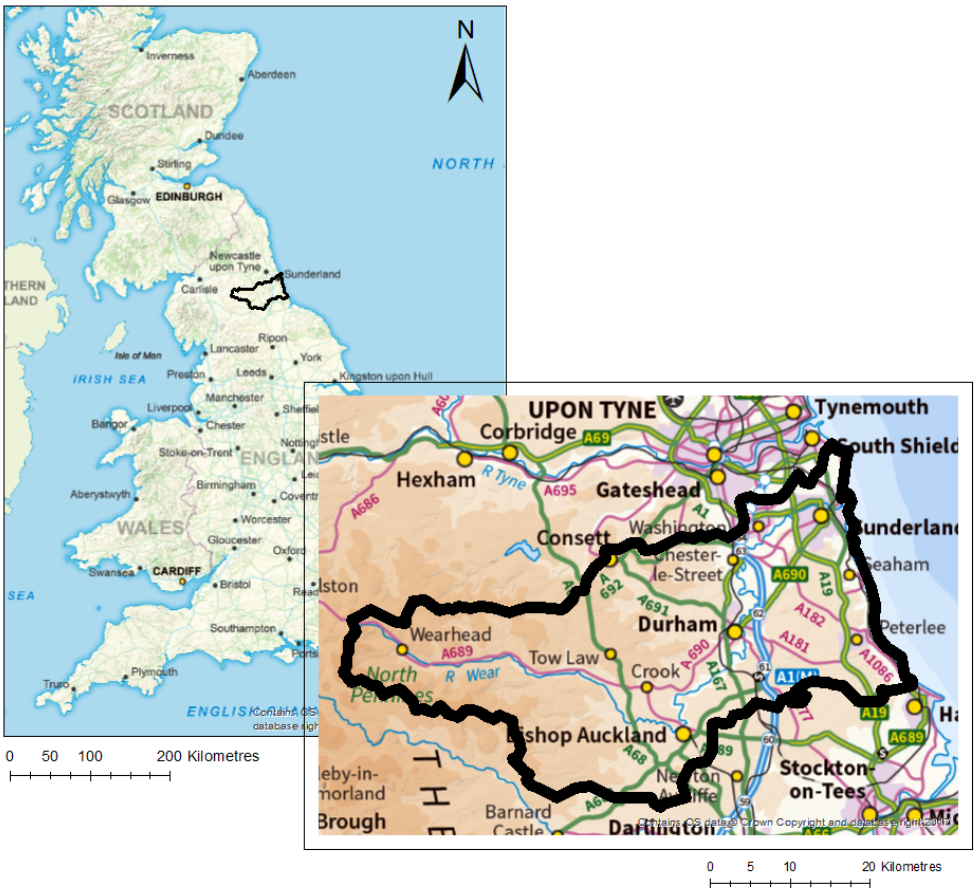

Figure 1.1: The River Wear Catchment located within the Northumbrian River District.

The rich industrial heritage associated with the mining of the Lower River Wear is due to the geology of the area, comprising a high abundance of coal fields in the Carboniferous limestone, millstone grit, coal measures, shales and mudstones, as well as metal mineralisation in the North Pennine lead-zinc Orefield. The extensive mining history of the Wear Catchment has led to several studies being conducted on water quality (e.g. Green *et al.*, 2000; Neal *et al.*, 2000; Shepherd *et al.*, 2009). Because of the historic mining legacy of the area, the Lower Wear has been subject to diffuse heavy metal pollution from mine-water discharge (Neal *et al.*, 2000). To help reduce pollution, schemes have been implemented, including small-scale passive treatments, such as reed beds, as well as larger-scale minewater pumping stations, to extract and treat contaminated discharges from disused mines, preventing contamination of surface and groundwaters (Environment Agency, 2008). Over the past 40 years, minewater pollution levels have been significantly reduced across the catchment (Neal *et al.*, 2000). The threat from contamination, however, is not yet over because of the existence of still contaminated land, and the continual need for pumping of former mine workings. Other sources of

pollution across the catchment are also of concern, including diffuse pollution[2] from agricultural land, and urban areas, as well as point-source pollution from sewage discharges. Recent improvements in sewage-treatment works have been of a benefit to water quality, however, several larger plants still pose a risk of having a negative influence on the quality of water (Our River Wear, 2012).

Besides pollution, there are other water-resource issues and threats to manage across the Wear Catchment. The River Wear, and its tributaries have a long history of flooding (National Rivers Authority, 1995). During a severe event, flood embankments at Bishop Auckland, Croxdale, and Shincliffe are at risk of overtopping. Properties and agricultural land including Page Bank, Sunderland and Durham are at risk of being inundated (National Rivers Authority, 1995). Within the catchment, future urbanisation of previously undeveloped land or redevelopment of land poses potential risks and implications to water supply, effluent disposal, solid waste disposal, flood defence, landscape and ecology (National Rivers Authority, 1995). Water governance in the Wear Catchment involves several public sector, private sector and voluntary charities/environmental non-governmental organisations (NGOS), including the Environment Agency, Northumbrian Water, local councils, the Rivers Trusts, and local academic institutions, as well as, businesses, schools and volunteers from the local communities. How the different groups and organisations who all have a connection with the River Wear come together to address and manage water issues is something that has received little or no attention. Using the Wear Catchment as a case study, focus is given specifically to the context and circumstances of water-resource management in the catchment, with validity to several aspects of improving understanding and management of river-related issues in a small area which can also be more widely applied to reflect the context of water governance in the UK as a whole.

1.2. Complexity in Water-Resource Management

The management of water resources is complex and uncertain (Chaffin *et al.*, 2016). Complex because the management of water resources crosses both biophysical and

[2] Dissimilar to point source pollution, diffuse pollution is often from a range of sources coming together to have a cumulative effect. Diffuse pollution risks include the runoff of fertilisers and pesticides from agricultural land into watercourses, erosion and poaching leading to soil loss into watercourses, and the runoff of chemicals and oils from urban areas.

administrative boundaries, within which there are many actors, often with competing interests, expectations and demands on water and the environment (Bellamy *et al.*, 2002; Ison *et al.*, 2007; Kerr, 2007). Combined with uncertainty associated with how social and ecological influences play out in often random, unpredictable ways, along with unknown influences such as climate change (Vörösmarty *et al.*, 2000), problems related to water resources have often been labelled as 'wicked' problems.

Wicked problems are complex and uncertain, and potentially insoluble (e.g. Rittel and Webber, 1973). In the coming decades with predicted climate change, population growth and declining environmental resources, scientists, citizens and policymakers are becoming increasingly concerned about how water resources should be managed (Royal Geographical Society (with IBG), 2012). At the catchment-scale, there are several competing needs of water, including improvements in water quality, flood management and equitable distribution and sustainable use of water resources (Royal Geographical Society (with IBG), 2012); ultimately, these competing needs must be understood and managed together, bringing together stakeholders at all levels. Such an inclusive, collaborative approach is fundamental in enabling the continued functioning of society, the economy and the environment, allowing all these needs to be met (Bandaragoda, no date).

Conventional water-resource management is focused on addressing water needs in isolation, without taking into consideration the potential impacts in the surrounding area or impacts that could arise in the future. Such an approach resulted in decreasing per-capita availability of water, degrading water quality, increasing competition and conflict within sectors such as society and the environment, for example upstream versus downstream, and highlighted the inadequacy of the institutional frameworks that have been used to address water-related issues (Safavi *et al.*, 2015).

Due to the increasing complexity of challenges, governments are continuing to be dependent on multiple actors to help achieve specific goals (Klijn, 2008). With regards to water resources, in recent years there has been a shift from more traditional disjointed water-resource management towards stakeholder collaboration, across horizontal networks as a way of working. Numerous types of governance system have emerged as a result, focusing on the complexity and uncertainty, dissimilar to the formerly more traditional technocratic solutions that have been used to deal with relatively more stable

and certain cause and effect problems. Alternative governance systems that have arisen focus specifically and more so on resilience, reflexivity and responsiveness (Termeer *et al.*, 2013), with specific emphasis on the groups involved in governing water (Meinzen-Dick, 2007). A general consensus amongst the approaches is the inclusion of the principles of adaptiveness, integration and collaboration, which together have led to the acceptance of normative principles of 'good water governance'. Good water governance according to the United Nations should be "participatory, consensus oriented, accountable, transparent, responsive, effective and efficient, equitable and inclusive and following the rule of law" (International Centre for Parliamentary Studies, 2018). Over the last 20 years, the EU, amongst other statutory bodies and governments has made an attempt to manage water differently by applying principles of good governance. This shift in governance has been promoted by international and national legislative changes, that have focused on localising decision-making, as well as emphasising participation in an attempt to manage complex and conflicting issues (e.g. Dewulf *et al.*, 2005; Faysse, 2006; Engle *et al.*, 2011). As suggested in the work of Ostrom (2007), it is important to recognise that no one governance solution to water fits all as there is variation between scales and environments. Despite difficulties in finding a governance solution, it still remains that "there is an urgent need to better understand and improve existing water governance systems" (Stein *et al.*, 2011: 1086), and ultimately:

> *"A major challenge is to find effective methods to analyse complex water governance arrangements, in particular the social dimension, which has often been neglected in the past (Pahl-Wostl, 2002c). Given the range and complexity of multi-actor natural resource governance arrangements, there is thus a real need to develop analytical tools and methodologies that can capture and translate such complexity".*
>
> **Stein *et al.*, 2011: 1085**

To address this major challenge, an innovative approach combining qualitative and quantitative methods in this research, specifically the use of SNA and ABM will be used to analyse the complex water governance arrangements in the UK, using the Wear catchment as a case study. Specific focus will be given to the social interactions of multiple actors working in the Wear catchment, investigating the complexities involved in working at the catchment-scale to manage water resources effectively.

1.3. Water-Resource Management in the UK

In recent years, the environmental governance approach in relation to water-resource management has experienced a shift away from top-down technocratic solutions, which were present in the early-mid 20th Century (Bonnell and Koontz, 2007), towards greater emphasis on holistic, landscape-scale considerations, as well as stakeholder and community involvement in managing water issues, as covered in the principles of IWRM. The concept of IWRM originated from the Brundtland Report (1987) and the Dublin Principles presented at the World Summit in Rio de Janeiro in 1992. Strategies for IWRM take into consideration the following points:

1. Water is a finite and vulnerable resource that is essential to sustain life, development and the environment, recognising the need for a holistic approach to water-resource management, considering all characteristics of the hydrological cycle and its interactions with the surrounding environment and other natural resources (Global Water Partnership, 2012a);
2. The need for the involvement of water development and management users, planners and policy-makers at all levels, recognising that water is a subject in which everyone is a stakeholder, and that only real participation can take place when stakeholders are actively involved in the decision-making process allowing for long lasting consensus and common agreement (Hendry, 2008; Global Water Partnership, 2012b);
3. The role of women is central to the provision, management and safeguarding of water, acknowledging the importance of women alongside men in decision-making processes related to water resources (Global Water Partnership, 2012c); and
4. The social and economic value of water which is that water has an economic value in all its uses and should be viewed as an economic good, and that the primary basic right of all people is access to affordable clean water and sanitation (Global Water Partnership, 2012d). Without consideration of the value of water it can result in inefficient, inequitable and environmentally damaging and wasteful uses of water resources (Global Water Partnership, 2012d).

Rather than stakeholders considering only isolated issues, as with conventional water management approaches, IWRM intends to allow for the recognition of interdependencies between water and land-use management, and the need for a stakeholder-oriented approach to reconcile competing interests and achieve multiple outcomes (Hendry,

2008). Several international conferences have been held to try and promote the concept of IWRM, and include: the Dublin Conference (January 1992), the Second World Water Forum and Ministerial Conference held in The Hague, The Netherlands (March 2000), the International Conference on Freshwater, Bonn (December 2001), and the World Summit on Sustainable Development, Johannesburg (2002) (Rahaman *et al.*, 2004). All four conferences highlighted the participatory approach, women's role in decision-making, water as an economic good, and the decentralisation of the management of water resources (Rahaman *et al.*, 2004). At The Hague, the notion that water can empower was expressed, benefitting women in particular, with the sharing of power and involvement with men in decision-making (Rahaman *et al.*, 2004).

The intentions of localising environmental improvement, involving a wide range of stakeholders in decision-making processes is expressed in the Water Framework Directive[3] (WFD). Since the introduction of the WFD in 2000, there has been a drive towards managing water resources at the catchment-scale, with the intentions of localising environmental improvement, involving the exchange of knowledge and expertise between locals and experts from a range of organisations including water companies, local authorities and academic institutions, to identify water issues and potential actions to address them (CaBA, 2015a).

The WFD has been dubbed a potentially ground-breaking and novel piece of legislation, integrating water quality, water resources and physical habitats. The overall purpose of the Directive is to establish a framework to be used for the protection of all European waterbodies including inland surface waters, transitional waters, coastal waters, and groundwaters, at the catchment-scale. As detailed in European Union (2010), the management of water resources according to the WFD is intended to:

[3] WFD – European Union Directive 2000/60/EC that commits all European Union member states to achieve good qualitative and quantitative status of all water bodies. Good ecological status is defined in terms of the quality of the biological community, the hydrological characteristics and the chemical characteristics of the given waterbody (European Commission, 2016). Parameters measured for the WFD include hydromorphological and physico-chemical parameters. Hydromorphological parameters are parameters associated with the physical characteristics of the shape, boundaries and content of a waterbody. Physico-chemical parameters are parameters associated with the physical chemistry of a waterbody. Examples include dissolved oxygen, pH and phosphorus.

1. Prevent further deterioration and protect and enhance the ecological status of aquatic environments;
2. Promote sustainable water use;
3. Enhance the protection and improvement of aquatic environments, with measures in place to reduce discharges, emissions and losses of priority hazardous substances;
4. Ensure the reduction of pollution of groundwater; and
5. Contribute to the mitigation of floods and droughts.

Two major goals following the implementation of the WFD were set, the first of which was the production of River Basin Management Plans (RBMPs) by 2009, which are required to be updated every six years thereafter, describing the river basins, sources of pollution, water-quality problems and any measures taken to solve the water-quality problems; and secondly, the achievement of good ecological status of waterbodies by 2015 (Verhallen *et al.*, 2001; Defra, 2016). Five categories for ecological status are defined, and are high, good, moderate, insufficient, and bad, with the assessment of the ecological status being made using biological, hydromorphological and physio-chemical parameters (Verhallen *et al.*, 2001).

In an attempt to achieve good status of all waterbodies, collaborative working at the catchment-scale is fundamental, including a range of stakeholders, enabling for environmental policy to be embedded into society. In doing so, collaboration allows for the building of trust and ownership with the local community which is dependent upon and impacts its surrounding natural resources and environment (Bonnell and Koontz, 2007). Ultimately, collaboration offers a means of balancing management between top-down regulations, such as the WFD, and bottom-up ideas and opinions of local stakeholders. Through combining the positive aspects of both management techniques, it is intended that collaborative approaches can indeed form an integral component of environmental management. Any collaborative process requires a good understanding of the actors involved. However, despite the recognition of, and drive towards collaborative working, there has been little focus on how the stakeholders come together in water-resource management, for example:

- Who are the stakeholders included in the collaboration?
- What role do the stakeholders play in the collaboration?

- What skills/expertise/information/resources do the stakeholders contribute to the collaboration?
- How are decisions made in the collaboration?

More specifically, there is opportunity to conduct analysis and building understanding of the rules of collaboration behaviour, attitudes, activities and evolution directions. Ultimately, by analysing the current state of collaboration in water-resource management, greater awareness of the stakeholders involved, and their roles will contribute to future progress made in terms of the management of water resources in the UK, and inform the strengths of the CaBA, as well as where there are potential flaws. Findings could be provided to stakeholders to inform of how to further improve their collaborations in water-resource management.

In 2011, eleven years on from the initial implementation of the WFD, progress had been made, with the production of RBMPs for ten River Basin Districts across England and Wales (Figure 1.2), and with the tackling of point source pollution (European Commission, 2010). However, further action was required in the tackling of diffuse sources of pollution and the integration of social and environmental concerns, and as part of the second round of RBMPs, 25 catchment pilot schemes (Figure 1.3) were initiated across England and Wales between May 2011 and January 2012 funded by Defra and the Environment Agency (CaBA, 2015a; Starkey and Parkin, 2015).

The introduction of the pilots offered a novel approach to address water-quality issues at the catchment-scale, offering a means of localising environmental improvement, focused on involving a wide-range of stakeholders in decision-making processes, encouraging stakeholder collaborations to identify issues and potential outcomes and actions to manage natural resources. The pilots demonstrated how it was possible to make use of local knowledge and expertise together with the knowledge and skills of organisations including environmental NGOs, water companies, local authorities, landowners and academics from across the UK (CaBA, 2015a). Together the organisations were able to start addressing problems associated with interdependent water issues such as polluted drainage discharges versus the need for freshwater, which can be abstracted and used for drinking or industrial purposes, as well as managing contaminated municipal and industrial wastewater that causes river pollution, threatening river ecology (Global Water

Partnership, 2010a), and therefore impacting the ecological status of the river system with regards to achieving the goals of the WFD.

Figure 1.2: River Basin Districts across England and Wales. The Wear Catchment is located within the Northumbria River Basin District (Environment Agency, 2015).

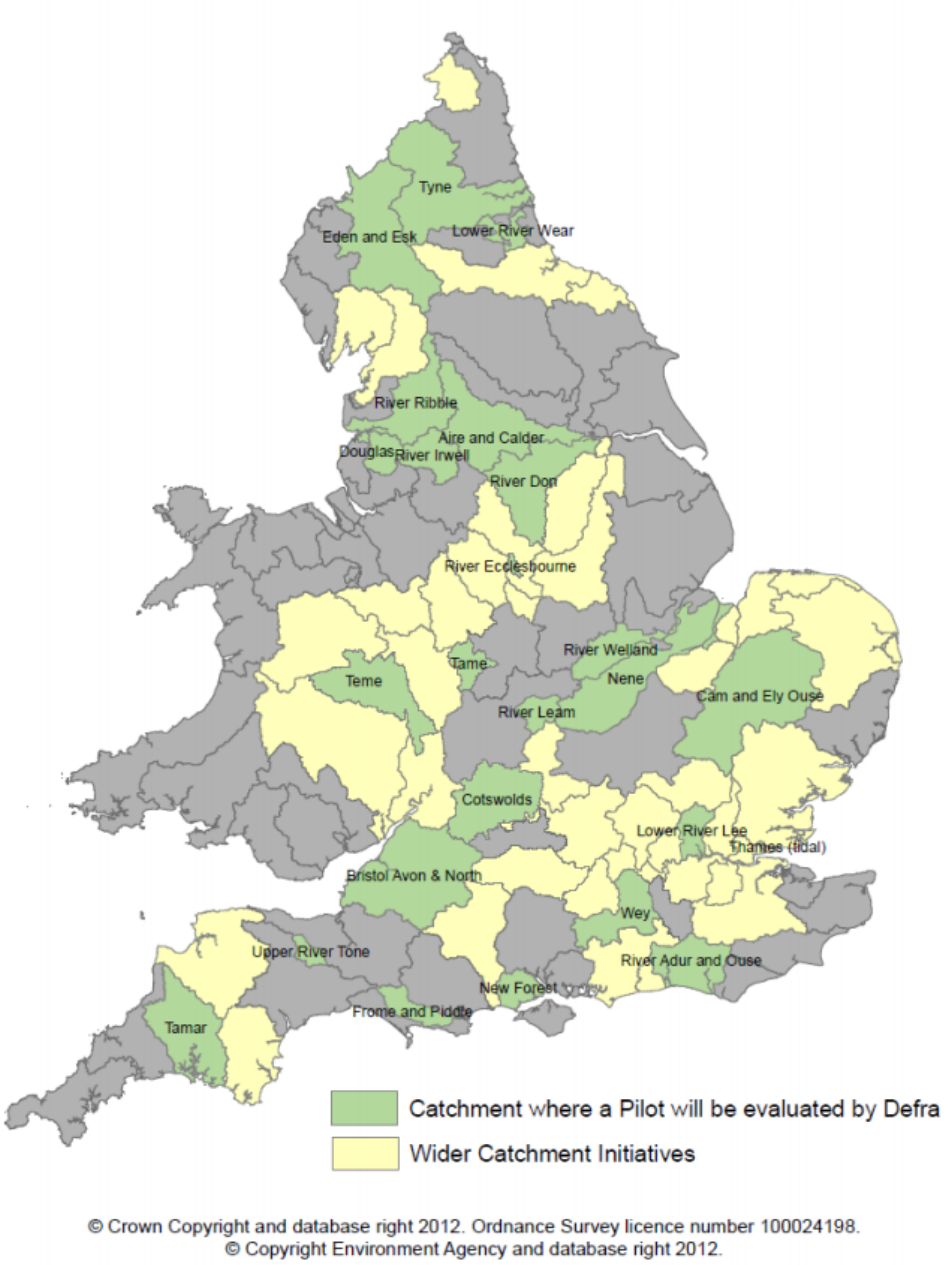

Figure 1.3: Catchments across England and Wales chosen for the pilot scheme in the CaBA (Defra, 2013).

The catchment pilots paved the way to trial a new way of tackling water issues at the catchment-scale, referred to as the CaBA. The CaBA[4] funded by Defra and the Environment Agency was launched in 2013 (CaBA, 2015a; Starkey and Parkin, 2015). The CaBA involves collaborative working at the catchment-scale, and is a bottom-up community-led approach with the intentions of delivering improvements to the water

[4] The CaBA is a community-led approach that engages people and groups from across society to help improve our precious water environments" (CaBA, 2015a).

environment (CaBA, 2015a). The objectives of the CaBA are to: (1) encourage collaborative working and transparent decision-making; (2) provide formal recognition for collaborative catchment partnerships; (3) encourage long-term self-sustaining funding arrangements; and (4) deliver a better water-quality environment (FWR, 2013).

The CaBA offers potential to address problems associated with interdependent water issues within the catchment such as polluted drainage discharges versus the need for freshwater which can be abstracted and used as drinking water or industrial purposes (Global Water Partnership, 2010). In addition, the CaBA also offers a means of addressing and managing contaminated municipal and industrial wastewater that causes river pollution, threatening river ecology (Global Water Partnership, 2010), and thus impacting the ecological status of the river system with regards to achieving the goals of the WFD.

To support the approach, an online CaBA forum was set up to allow stakeholders involved in the CaBA and wider catchment-management processes to interact and communicate, to post topics of interest and to upload and view information (Starkey and Parkin, 2015). The overall aim of the site is to support those involved in the approach and to support best practice of the management of water resources at the catchment-scale (Starkey and Parkin, 2015). Alongside the online forum, an online hub named the Catchment Management Hub was set up, with the intention of providing catchment stakeholders as well as members of the public with a central place to find, share and comment on the catchment information (Starkey and Parkin, 2015). The setting up of the Hub was fundamental in that as stakeholder collaborations grow, and communities become increasingly involved in catchment management, it is essential to have an information source and place for central communication with the co-production and collective use of tools and materials (Starkey and Parkin, 2015). The sharing of knowledge and expertise is crucial in working towards ensuring input and active involvement from all, and that people's voices are heard, no matter their level, from the community-level through to the government-level.

The Wear Catchment is one of the catchments included in the CaBA programme, with the Wear Rivers Trust being appointed as the catchment host (CaBA, 2015b). Stretching from the eastern Pennines to the North Sea coast, there are many changes in land-use and land cover with various stakeholders including local authorities and landowners along the River Wear and its tributaries, promoting the need for an integrated and co-ordinated

management approach (CaBA, 2015b). In the Wear Catchment, stakeholders involved in the CaBA, include, but are not limited to: the Environment Agency, Durham University, Groundwork Northeast, Northumbrian Water, Durham County Council and the Coal Authority (Catchment Change Management Hub, 2012). Bringing together the stakeholders, the collective group implementing the CaBA is the Wear Catchment Partnership. A Catchment Partnership is defined as a "multi-stakeholder group working at the catchment level to agree and deliver strategic priorities for the catchment and to contribute to the relevant River Basin Management Plan" (FWR, 2013: 2).

In the Wear Catchment, key sites for investigation have been identified, and include: the River Twizell, the Lumley Park Burn, the River Gaunless and the Croxdale Beck, with key issues including surface water[5] and groundwater[6] quality (Catchment Change Management Hub, 2012). A recent project involving members of the Wear Catchment Partnership is the European Union Topsoil Interreg Project (referred to herein as the Topsoil Project). Introduced in December 2015, the Topsoil Project aims to understand fully the near surface-groundwater interactions in the top 20-30 cm of the subsurface (topsoil). The functioning of the critical interface with the subsurface zone can directly, rapidly and seriously impact aboveground features and activities, including urban infrastructure, utilities and agricultural operations; and could be amplified in the future by climate change with associated changes in precipitation patterns and intensities.

Focusing on the North Sea Region, with groups from the UK, the Netherlands, Belgium and Germany, specific challenges in the upper subsurface are faced by transnational partners. The intention of the Topsoil Project is to develop transnational best-practice, through the exchange of knowledge, and by understanding technical investigations and analysis, mitigation measures and actions planned and delivered through effective stakeholder co-operation. Regarding the Wear catchment, the two strands of the Topsoil project are as follows:

1. To investigate the interaction between surface water and groundwater, at the transitional zone between the Magnesian Limestone and coal measures, and to

[5] Surface water – Water present on the surface of the Earth, including, rivers, streams, lakes and reservoirs.
[6] Groundwater – The water present beneath the Earth's surface in soil pore spaces and in the fractures of rock formations.

understand surface-groundwater processes across a complex, contaminated and highly modified catchment; and

2. To inform strategy on development through the CaBA, and to inform stakeholders on management practices.

Ultimately, the end goal of the project is to develop a conceptual model that can be used by stakeholders within the catchment who are responsible for water management to inform decision-making, on how best to manage and protect the quality of water resources. For example: on where it is best to store floodwaters, where best to abstract drinking water; and how and where development could have detrimental impacts on water quality.

1.4. Principal Modes of Exploration

In order to better understand the catchment-management system a number of approaches and perspectives have been connected. Utility and modes of exploration are presented as an understanding that processes of catchment management can be conceptualised holistically as a system, with component parts and dynamics identifiable through the study of interactions (human-human and human-environment). A catchment system is not reducible to its components or parts or interactions and is complex and adaptive, and systems can both be spatial and aspatial conceptualisations. They can be associated with a particular locality and include aspatial dynamics. The concept of a networked system is real but only as a representation of time-independent histories of action and interaction and is not the only way that dynamics can be understood. Whilst aspects of networks and connections can be conceptualised and depicted, no agency is attached to networks of entities, only to the institutions that emerge. Stakeholders are considered as important agents of change in a governance system and their decisions, actions and interactions are important in shaping approaches.

ABM offers a way of being able to investigate the interactions and actions of stakeholders, building upon analysis carried out using SNA. Using an agent-based modelling approach, a model can be created that is representative of a particular conceptualisation of a real-world system and can be used as a tool to develop understanding. These principles feed into the utilisation of the perspectives further introduced in the following chapter to help build a new understanding of the complexities of the catchment-management process in

the UK. It is recognised that such perspectives and methodologies are not the only ways a catchment-management system can be understood but aim to show how they can be used to develop knowledge that might identify unique characteristics, successes, challenges and practices that may be useful for furthering knowledge in general and specifically in relation to governance processes.

1.5. Aim

The aim of this research is to analyse the current state of water-resource management in the UK, investigating the complexities of water governance arrangements, in particular the social dimension, using the Wear Catchment as a case study.

Despite the introduction of the CaBA focusing water-resource management at the catchment-scale involving a wide-range of stakeholders from all levels, including the public sector, the private sector and the voluntary sector comprising environmental NGOs and charities, there has been little, or no attention paid to the interactions, roles and communication between stakeholders. To understand such interactions and processes, the social network of stakeholders needs to be analysed.

1.6. Objectives

To achieve the aim of this research, the following objectives are proposed:

1. To identify stakeholders involved in water-resource management in the Wear Catchment.

The key focus of this research is on stakeholders involved in water-resource management in the Wear Catchment, to understand the current ways of working in managing water resources. The identification of stakeholders involved in water-resource management in the Wear Catchment will form the basis of the SNA.

2. To undertake a mixed-method approach comprised of qualitative and quantitative data collection to identify the network of stakeholders working in the Wear Catchment, and their roles within the network.

An integral component of this research is to utilise existing stakeholders, making use of pre-existing stakeholder contacts. The rationale for this objective is to identify what water issues stakeholders are addressing, i.e. who stakeholders work with, both individuals and

organisations, what stakeholders get from one another, data being an example, and the relative importance of relations with different stakeholders through the process of ranking.

3. To employ the method of SNA to analyse the stakeholder network, identifying for example: key stakeholders in the network; connections present between stakeholders; and any stakeholders who are part of the network yet remain on the peripheries.

SNA will allow for the analysis of the network of stakeholders identified, providing an insight into the relative involvement of stakeholders in the network, through the employment of analysis tools, such as degree centrality, and path length between stakeholders. Through better understanding of the components of the catchment-management system, breaking down its complexity and looking at the relationships and interactions between the stakeholders involved. Exploration of the actions and interactions between the stakeholders is intended to lead to better understanding of the interconnectedness of the system. By investigating the components of the system that can be understood as drivers and barriers of the successes and failures of the system, and the ability of the stakeholders to work collaboratively at the catchment-scale in the management of water resources. Breaking down the complexity of the system and understanding the elements of the system gives rise to the possibility of understanding the interactions of multiple factors, and thus the exploration of what contributes to good or effective practice in water-resource management.

4. To use ABM to explore the possible outcomes of changes made to the stakeholder network, feeding in qualitative and quantitative data collected, using the stakeholder network identified, and to analyse and evaluate the current state of water-resource management in the Wear Catchment relative to possible future scenarios of change.

ABM will allow for the findings from the empirical data collection to be utilised, to provide an insight into how changing stakeholder behaviours could potentially impact upon collaborative management. A limitation of SNA is that it only provides a snapshot in time (O'Sullivan *et al.*, 2012). Therefore, incorporating and bringing together SNA with ABM offers a means of overcoming temporal issues. By investigating further, the relationships between the behaviour of the stakeholders, the enablers and the barriers in collaborative workings, and thus the outcomes in the management of water resources, then there is an

opportunity to understand the management processes within the system better. The use of ABM allows for the investigation of possible future scenarios of change with regards to stakeholder collaboration in water-resource management, making use of knowledge and understanding of the interactions and behaviours of the stakeholders involved.

5. To use the findings from the research to help inform the wider picture of water-resource management both with specific reference to the Wear Catchment, and beyond to the regional and national levels of the UK.

The findings of this research will be disseminated to stakeholders involved in water-resource management in the Wear Catchment with the intentions of being used to start discussions and to inform them of the current ways of working, and potential future changes that could be made to improve management practices to achieve the goals of the WFD, for example. Hopefully from such discussions, the stakeholders will be able to build upon and improve their existing ways of working.

1.7. Summary

Chapter 1 started by giving an overview of the case study used in this research, the Wear Catchment. Detail was given on the characteristics of the catchment, as well as a history of the mining activities and the water-resource issues and threats. Moving beyond the Wear Catchment, a broad overview of the complexity involved in water-resource management was given, briefly describing the traditional approach to the management of water resources, and more recently the drive towards the need for greater integration and collaboration amongst stakeholders at all levels to address the complex challenges in managing water issues. An overview of water-resource management in the UK was given, detailing strategies for IWRM along with background to the WFD. For the WFD, detail was provided on the goals of the Directive, along with the use of River Basin Districts and their corresponding RBMPs. Following on, detail was given on water-resource management being carried out at the catchment-scale, going into detail on the CaBA, linking back to the Wear as one of the catchments included in the approach. In relation to the implementation of CaBA, information on the Wear Catchment Partnership was provided, along with information on the more recent partnership working involved in the Topsoil project. The remainder of the chapter detailed the principal modes of exploration used in this research, along with the research aim, objectives and research questions. Finally, a

summary of the research focus is given along with an overview of the thesis structure and the content of the chapters.

1.8. Thesis Structure

Chapter 2 starts by giving an overview of the concepts of governance and management with the focus being on the environment, providing detail on how the two concepts come together, and are applied in water-resource management. A review of the participation of stakeholders in water-resource management is given, including a critique of what constitutes a stakeholder, drawing comparisons between experts and non-experts, and how a stakeholder can be defined. From the critique of what constitutes a stakeholder, detail is given on how participation has emerged as an approach to enhance natural-resource management, drawing on examples from the involvement of the public. Three key principles in the management of natural resources, namely, integration, adaptation and collaboration are introduced, including definitions and how they come together, feeding into the WFD. Owing to the complexity involved in water-resource management, the concept of systems thinking to understand complexity using examples from socio-ecological systems is introduced. Reference is made to social capital and social learning, detailing the importance of social relationships, linking into the following section on using a network approach to understand water-resource management systems, and the social relations amongst the stakeholders. The concept of 'wicked problems' in the context of water-resource issues is expanded upon from Chapter 1, building upon the discussion of complex systems, and the opportunity to use a network approach to address the problems. Background is given to SNA, and how it was used in this research. Moving on, detail is given on ABM, and how it can be used in combination with SNA together as an innovative approach to analyse the complex water-governance arrangements, in particular the social dimension, and the ability to test future scenarios of change. The final section of the chapter draws on links to the work of Mason (2006), referring to the bringing together of qualitative and quantitative methods, highlighting the innovative thinking of this research and the 'dialogic tensions' that arise from such an approach.

Chapter 3 introduces and details the context and data-collection methodology used in this research. A detailed description of the case-study location, the River Wear Catchment, which was deemed to be an appropriate place to investigate the current state of water-resource management in the UK is provided. In the description of the Wear Catchment a

review of the implementation of the WFD in the catchment is given, detailing the CaBA, and the transition from a pilot phase into the full roll out approach across the whole of the Catchment. The remainder of the chapter focuses on the approach for data collection, combining a survey and interviews to gather information from stakeholders working in the Wear Catchment regarding the involvement and roles of stakeholders with whom they communicate and work alongside in the management of water resources. Included with the description of the data collection methods is detail on the approach used in the identification and recruitment of research participants, as well as recognition and reflection on potential ethical implications associated with the collection of data, and researcher positionality.

Chapter 4 investigates the social-network of stakeholders currently involved in water-resource management in the Wear Catchment. Background information is given on the methodology involved in SNA, including the use of the survey data collected, and the translation of the data into a network. In-depth analysis was conducted on the network, including who the key central stakeholders in the network are, namely the Wear Rivers Trust, the Environment Agency and Northumbrian Water, along with the identification of stakeholders at the peripheries of the network. The purposes of ties the stakeholders have with others in the network is also investigated. Removal of the core stakeholders that could have detrimental effects on the structure and functioning of the network is discussed, and subsequently the potential impacts on the management of water resources in the catchment. A detailed description of the characteristics of the network is also provided, using network metrics including centrality. The remainder of the chapter comprises the discussion and interpretation of the network, with an assessment of the current state of the CaBA in the Wear Catchment based on the SNA.

Chapter 5 provides a thematic analysis of the interviews conducted with representatives from stakeholder organisations involved in water-resource management in the Wear Catchment, expanding on the SNA in Chapter 4, further developing awareness and knowledge of the relationships between stakeholders. The chapter addresses a number of themes encompassed by the processes of communication and exchange. Topics of discussion include, the exchange of data and/or information between stakeholders, the balance of giving and receiving of time, data and information between stakeholders, and the support offered by stakeholders to others. Linking to these topics are the broader themes of trust, reciprocation, and the challenges associated with power and hierarchy.

Chapter 6 provides detail on the use of ABM in this research. Using ABM with the data collected on stakeholder interactions in the Wear Catchment adds an additional level of depth to the findings of the study. ABM is used as a "computational petri-dish" (Miller and Page, 2007), providing a means of investigating potential scenarios of change in the communication and in the ability of the stakeholders to interact within the Wear Catchment Partnership. The results of the ABM exploration offer a bridge to ways in which the findings of this research are applicable to the real-world, providing insights into the current state of water-resource management system of the Wear Catchment, with the potential to start stakeholder discussions on where changes could be made in their behaviour and working practices to improve the efficiency of their working and in the implementation of the CaBA. Ultimately, changes to the working practices have the potential to lead to improvements to the water environment, including achieving, e.g. the goals of the WFD.

Chapter 2 – Literature Review

The purpose of this chapter is to provide the theoretical foundation of this research, giving background information and understanding of the development of approaches to water management, characterising the catchment-management system, and its dynamics, presenting a critical review of core themes and theory in order to provide a theoretical foundation for the research. Past and current thinking with regards to water-resource management is presented, covering concepts relating to water-resource management, governance, and systems. Specific understandings of processes related to and that affect and produce management practices relevant to water-resource management are critiqued with reference to outcomes on governance approaches, providing a further theoretical basis for this research.

As part of the change in the approaches to management, reference is made to the WFD. Collaboration is introduced as an approach to environmental management, detailing its origins, and the key principles of participation, co-production of knowledge, and social capital, going into detail on social learning. Building upon this discussion, a critique of what constitutes a stakeholder is given, detailing the identification of stakeholders using stakeholder analysis, and the investigation of the networks in which they are involved using SNA, and how there is opportunity to incorporate such data and analysis into ABM approaches to investigate changes in network structures to analyse the current state of collaborative water-resource management in the UK.

2.1. Concepts of Governance and Management

One of the concepts of governance is that governance involves a series of interorganisational processes, networks and structures that include individual and collective action, that are brought together through a series of informal and formal rules (Young, 1992; Rhodes, 1996; Lebel *et al.*, 2006). Peters and Pierre (1998: 232) define governance as "essentially a political theory – insofar as it describes a certain type of exchange between the state and the society". One reason that principles of environmental governance may have arisen is due to the limited capacity of conventional governance arrangements to explicitly deal with so-called wicked problems (Ludwig, 1990). The concept of environmental governance also emerged as an explanatory concept linking to

social and economic change regarding legitimacy of natural states and environmental resource issues (Bridge and Perreault, 2008).

The governance concept emerged in the Anglophone world, and in the 1980s and 1990s, change in social and political structure, an alternative to state dominance, facilitated by the newly elected governments of the UK, USA, Australia and New Zealand (Goodwin, 2009). The emergence of governance was supported by the growth of coalitions and partnerships involving political actors from the voluntary and private sectors, causing a shift in the decision-making structure, and a change to the institutional map of governance (Goodwin, 2009). With this, the definition of governance proposed by Rhodes (1996: 652-3) is appropriate, "[governance] is a change in the meaning of government, referring to a new process of governing; a changed condition of ordered rule; or the new method by which society is governed".

The concept of governance is broader than government, with governance being a multi-scalar process involving multiple actors. According to Goodwin (2009), governance can be referred to as a multi-level operation, which references a political system within which decision-making powers are shared across space and place between different territorial levels between local, regional, national and international networks. The definition of governance here problematises state-centred forms of regulation and administrative powers (Bridge and Perreault, 2008), and that political authority is not restricted to one place, operating across several different spatial scales (Painter, 2000; Lemos and Agrawal, 2006). Therefore, indicating shifts in the institutional balance of power (Bridge and Perreault, 2008). Stoker (1998: 18) proposes five propositions that refer to governance as a framework that can be used to interrogate the changing ways that society is governed:

1. Governance is a set of institutions and actors drawn from and beyond government;
2. Governance identifies the blurring of boundaries and responsibilities in tackling social and economic issues;
3. Governance identifies the power dependence involved in the relationships between institutions involved in collective action;
4. Governance is about autonomous self-governing networks of actors; and
5. Governance recognises capacity to get things done – rather than resting on the power of the government to command or use its authority, government is used as a guide.

Environmental governance is an emergent concept from the study of governance. Bridge and Perreault (2008: 488) define environmental governance as "a broad analytical framework for addressing the institutional arrangements, spatial scales, organisational structures and social actors involved in decision-making around different environments and resources". The nature of environmental governance is viewed as adaptive, specifically focusing on actor involvement, with cross-scale interactions having self-organising capabilities extending beyond government and collaborative arrangements such as networks and partnerships, allowing for the processes of learning, social learning, collaboration and co-management operations to occur (Folke *et al.*, 2005; Huitema *et al.*, 2009). Governance networks (Klijn, 2008) allow for horizontal interactions challenging perceived hierarchies of stakeholders through their web of interconnected relationships and interdependencies with other stakeholders. Understanding of these networks is important, in particular when commitment to collaboration is given (see Section 2.6 for discussion of networks).

2.2. Change in the Governance of Water-Resource Management in the UK

Change in the governance of water-resource management in the UK has developed through a change in legitimate knowledge, informal institutions and decision-making behaviour. In particular the desire for the localisation of decision-making via new structures, roles and support systems has led to the formation of a more collaborative governance approach. Emerson *et al.* (2012: 2) define collaborative governance as:

> *"the processes and structures of public policy decision-making and management that engage people constructively across the boundaries of public agencies, levels of government, and/or the public, private and civic spheres in order to carry out public purpose that could otherwise not be accomplished".*

According to Ostrom (1990), collaborative governance involves jointly determined norms and rules to regulate group and individual behaviour. The word governance is not synonymous with management (Stoker, 1998). Management, for example, natural-resource management or IWRM are terms typically used to describe wider structures, procedures and processes in operation that either create or hinder the conditions in which decisions are made and actions are implemented (Armitage *et al.*, 2007; 2012). In

the context of water resources, the word management has been used to describe "operational activities including the operation, monitoring, strategic planning, and implementation of measures" (Pahl-Wostl, 2009: 1). Management is thus focused on the day-to-day operation on the ground, used in relation to managers and processes of practice. Managers are the active agents involved in problem-solving, with the intentions of achieving desired change in the system. Much of the operational language in water-resource management is focused on management, and is a term used by practitioners and policy makers in water-resource management, for example in the WFD RBMPs (Watson, 2014). Effective water governance, through the creation of policies such as the WFD requires continuous monitoring of the water environment, as well as proper implementation of the policies by members of the governing bodies, which in the case of the WFD are stakeholders involved in the management of water resources, including the Environment Agency, water companies, and environmental NGOs. An important aspect of governance is the balancing of powers of the members and their roles, so as to ensure that efficient and best working practices are implemented.

2.3. Participation of Stakeholders in Water-Resource Management

Within the field of Science and Technology Studies, the role of stakeholders has visibly changed over the last 200 years (Jasanoff *et al.*, 1995). Since the late 19th Century, Lengwiler (2008) proposed four periods in which the conceptualisation of what constitutes a stakeholder changed: (1) **hybrid period** – individuals were at once politicians, scientists and citizens; (2) **politicised period** – science as a discipline set experts and expert knowledge apart; (3) **autonomous period** – public spending on science increased and institutions were formed; and (4) **participatory period** – non-scientists, citizens and lay people began to be included, with a drive to including all areas of society (Kindon *et al.*, 2007).

However, there is a debate of what or who constitutes a stakeholder, and whether they are experts or non-experts based on their relative legitimacy. Collins and Evans (2002) outlined the need for the reconceptualization of stakeholder legitimacy with reference to their expertise, suggesting three levels of expertise: (1) no expertise, (2) interactional expertise, and (3) contributory expertise, the latter of which is sufficient expertise to be able to contribute to the science of the field that is being analysed. This idea was critiqued

by Jasanoff (2003), who argued the need for deeper consideration of contexts in which certain types of knowledge and expertise are created and sustained, in relation to politics of the everyday and institutional processes associated with an understanding of agency through knowledge legitimisation. The notion that knowledge is socially constructed was proposed by Callon (1999) through the co-production of knowledge model, in which knowledge is created through deliberative processes.

Despite the wide use of the term stakeholder, there is also little consensus of its definition (Mitchell *et al.*, 1997; Jonker and Foster, 2002). Over a 40-year period and across 75 texts, Friedman and Miles (2006) identified 55 definitions of a stakeholder. From literature searches, Carroll (1993) identified stakeholders as: shareholders, competitors, employees, communities, customers, special interest groups, social and public at large, local, national or international pressure groups (Scholes and Clutterbuck, 1998), managers, suppliers and creditors (Hill and Jones, 1992). Ultimately, a stakeholder is an individual, or group of individuals who have a stake, or interest, in a particular issue, topic or project, etc.

Freeman's (1984: 25) business management definition of a stakeholder is useful, whereby a stakeholder is "any group or individual who can affect or who is affected by the achievement of the firm's objectives". According to Reed and Curzon (2015), it is an all-encompassing definition that can be applied to a wide range of individuals, groups and organisations regardless of level of power and influence. Despite the age of Freeman's definition of a stakeholder, it is still considered to be the most balanced definition (Schiller *et al.*, 2013).

The process of identifying stakeholders is referred to as stakeholder analysis or stakeholder mapping (Reed *et al.*, 2009). Stakeholder analysis (1) defines aspects of a social-natural phenomenon affected by a decision or action, (2) identifies individuals/groups/organisations who are affected by or can affect those parts of the phenomenon (including humans, non-humans, future generations), and (3) prioritises these individuals and groups with involvement in decision-making.

Bearing the above in mind, the definition of a stakeholder used in this research is someone whose view of an issue or problem at stake, is unique, contextual and subjectively bounded, but yet remains possible to be shaped and stretched by others to be combined

and reimagined so as to better define the problem or solution to the problem. Such a definition underpins the current theoretical approaches used in water-resource management in the UK and across Europe. With, for example, the WFD there is a current focus in water-resource management on the representative and democratic process, dubbed by Jasanoff (2003) as 'the participatory turn'. Participation is central to problems and challenges of natural resource management, including catchment management (Gleick, 2000; Mostert *et al.*, 2007; Lane *et al.*, 2011).

Participation has emerged as an approach to enhance natural-resource management (Luyet *et al.*, 2012). Public participation has been part of several environmental applications including watershed management (see, Kenney *et al.*, 2000; ISPWDK, 2005; Sabatier *et al.*, 2005), and also reflected in a number of international agreements including the WFD (Luyet *et al.*, 2012). There are various definitions of participation, varying depending on the decision-making processes and who should participate (Luyet *et al.*, 2012). For example, Luyet *et al.* (2012) use the definition of participation from the World Bank (1996: 3), as "a process through which stakeholders influence and share control over development initiatives and the decision and resources which affect them".

An example of the involvement of the public in decision-making is a study conducted by Lane *et al.* (2011). In their paper, they describe an experiment whereby the position of scientists with respect to flood-risk management was changed, and by engaging and involving the public, worked on the co-production of knowledge to reduce flood risk. Experts were classed as both certified experts (academic natural and social scientists), and non-certified experts (locals affected by flooding) (Lane *et al.*, 2011). The importance of including opinions of all expert decision makers, including the public, is also expressed in the work of Cook *et al.* (2015). Their paper focuses on the emergence of alternatives to traditional technical flood management, which is focused on the prediction of the physical control of rivers and their catchments, towards innovative alternatives.

The co-production of knowledge and redistributing expertise is a topical area of interest with regards to participatory flood modelling. Landström *et al.* (2011) discuss the potential of computer-simulation modelling in offering opportunities for redistributing expertise between scientists and the affected public with regards to environmental problems. It is intended that through the use of competency groups that it will be possible to harness the energy generated by public controversy and enable other than scientific

expertise to contribute to the generation of environmental knowledge (Landström *et al.*, 2011). This recognition of the need to encourage interdisciplinary working between traditionally disparate management sectors and groups is also recognised in the work of Rollason *et al.* (2018). Rollason *et al.* (2018) propose the need for the engagement of communities in integrated catchment management, and the notion of them being central in the promotion of participatory governance and management decision-making in the management of water resources.

Despite general acceptance of participation in water-resource management, one key thing is that it is not always made clear is what distinguishes stakeholder participation from public participation (Luyet *et al.*, 2012). Distinctions are often made between the terms public and the stakeholders, but are terms that are not always used consistently, therefore leading to confused understanding (Luyet *et al.*, 2012). One way of defining the public is as a collection of individuals who are generally unstructured and unorganised (Kessler, 2004; Luyet *et al.*, 2005). With regards to the management of environmental resources, integration as a principle offers a means of being able to investigate and understand how stakeholders are involved and work together (or not as the case may be).

2.4. Integration, Adaptation and Collaboration

Integration, adaptation and collaboration are three key principles in the management of natural resources. A combination of the three is deemed to be good practice. Within the context of catchment management, Bisset *et al.* (2009) views the three principles as follows:

1. **Integration** – a set of common issues, objectives, types of information or stakeholders in a catchment are identified and involved that can allow for multiple goals to be achieved;
2. **Adaptation** – a planning process that can anticipate, accommodate and respond to change; and
3. **Collaboration** – different stakeholders work together to agree actions and to achieve goals.

Integrated environmental management acknowledges the interconnections between the human and physical systems involved (Moote *et al.*, 1994), and has become a key part of water-resource management in relation to the creation of policy and governance

(Margerum, 1999; Biswas, 2004; Lubell and Lippert, 2011), referred to as IWRM. IWRM promotes coordinated development and management of water, land and related resources, with the intentions of maximising socio-economic welfare, equitably and sustainably (Global Water Partnership, 2010).

Adaption is relevant in complex natural-resource management issues, where uncertainty and non-linearity are present, for example in water-resource management (Armitage *et al.*, 2009). Adaptive management can be defined as 'learning by doing' (Walters, 1997), to better understand response patterns by examining management actions and their effectiveness in practice. By gaining understanding of feedbacks and dynamic processes, it can inform new policies and practices.

Collaborative management is a key mode of delivering integrated and adaptive management, offering an alternative to more traditional top-down environmental management approaches (Sabatier *et al.*, 2005). Gray (1989: 3) defines a collaborative approach as "[offering] the opportunity for those with divergent view-points to explore their differences and search for solutions that go beyond their own limited vision", for example, catchment-partnerships in water-resource management. Although it is difficult to pin-point an exact universal definition of a collaborative approach, it includes key aspects, including: participation in which all stakeholders are valued and included, balancing power and social learning, giving way to core values such as empowerment, openness, reciprocity and holistic understanding of the environment working in collective action towards a common aim of environmental improvement. Core themes often explored in collaborative studies include the exchange of data, knowledge and evidence, and the presence of trust and trusted relationships, facilitated by ideas of what constitutes expertise and legitimacy.

The number of and diversity of actors and sectors involved in environmental management is a key challenge, as each have their own perceptions, interests and resources (Robinson *et al.*, 2011). In the past 20 years, collaborative water partnerships have emerged with the intentions of reconciling multiple complexities associated with the management of water resources by encouraging stakeholders at all levels to take equal part in decision-making within a catchment area as a result of collective coordination of values and ideas. The inclusion of stakeholders from all levels is based on the principle that by combining views a much more universally coherent definition of a problem can be found, hopefully resulting in better choice of collective action (Steins and Edwards, 1998).

More recently in water-resource management, collaborative management under the CaBA is driven by the WFD. From the perspective of implementing the CaBA, the main characteristic of collaborative working in the 'Guide to Collaborative Catchment Management' (FWR, 2013) is that "decision-making, risks and ownership are shared. Decisions are made jointly regarding policy development, implementation, evaluation and adjustment". Figure 2.1 shows the underlying principles, values and features of a collaborative approach from the work of Tindale (2013), based on a synthesis of studies in collaborative environmental management.

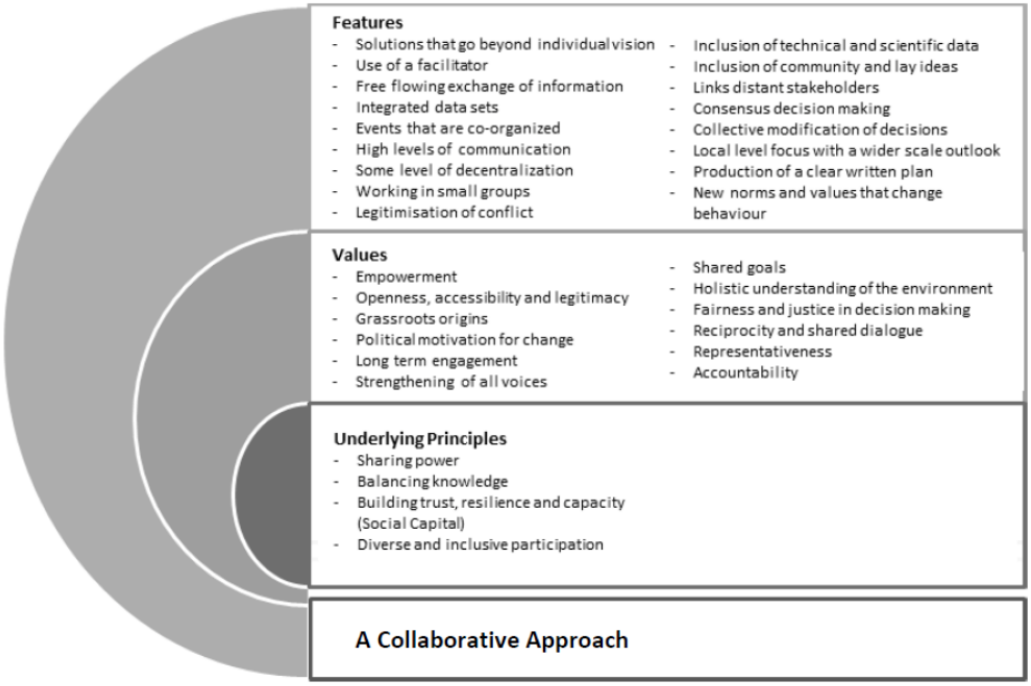

Figure 2.1: Conceptualisation of the components of a collaborative approach, including the underlying principles, values and features (Tindale, 2013).

Figure 2.2 reflects the changing attitudes to environmental governance with the implementation of the WFD, focusing on collaborative management, with greater appreciation of the importance of the inclusion of stakeholders at all levels. As Cook *et al.* (2012) have incorporated into the figure, there is progress to be made, with disjunctures existing between stakeholder groups, for example, between local communities at the catchment-scale and the larger, higher level UK and international governments at the top end of the management spectrum.

Watson (2014) highlights difficulties often faced by striving towards and pushing for multi-party collaboration, especially in relation to the depoliticised narrative where stakeholders are viewed as equals, and the role of power is paid little attention. From an in-depth study of the collaborative processes in the pilot-phases of CaBA, Watson (2014) concluded that the CaBA is limited by unequal power relations amongst stakeholders involved. Collaborative efforts can also take large amounts of time and resource commitments (Kenney, 1999). Cortner and Moote (1999) argue that collaborative processes can sometimes be implemented ineffectually, thus causing problems around lack of representation in cases where a high diversity of stakeholders is required (Coggins, 1999), owing to the settling of unrealistic expectations of the theoretical ideal of collaboration. Even in cases when collaboration is fully implemented, the process of implementation can still have negative effects, for example, the collaboration groups increasingly focus on smaller areas, especially regarding catchment-scale (Rudeen *et al.*, 2012). As a result, local voices become privileged, breaking the links between local and distant stakeholders (Rudeen *et al.*, 2012). Understanding of the complexities in how stakeholders come to work together, in the case of water-resource management is of great importance and will be addressed in this research.

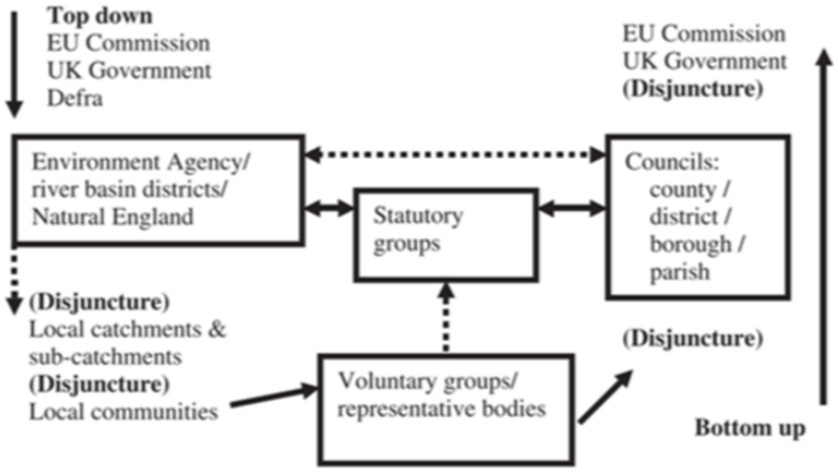

Figure 2.2: Structure of current water management in the UK (Cook *et al.*, 2012).

2.5. Systems in Water-Resource Management: Understanding Complexity

Systems thinking is a framework that can be used to approach the complexity of a system and offer a means of being able to conceptualise it. Ison *et al.* (1997) describes systems thinking as starting to look at, analyse and uncover different and in some cases conflicting views, positions, opinions, actions and perspectives that stakeholders have, showing important aspects of complex natural-resource systems. Many processes in ecology and society are associated with non-linearity and uncertainty (Berkes *et al.*, 2003). Cilliers (1998) describes how complexity is inherent in the characteristics of the system, arising from the interactions of the components of the system rather than from the individual properties of the components. According to Cilliers *et al.* (2013), key characteristics of complex systems are: systems made up of a large number of components that influence each other through interactions; interactions that are often non-linear, creating feedback loops in the system, and are short-range, i.e. the components are unaware of the system as a whole; and, the system is an open system that is constantly evolving through time with history playing an important part on present behaviour, and the extent to which the system can be described is dependent on the position and framing of the observer. In the context of water-resource management, catchments can be viewed as complex systems, with multiple and competing actors and values, along with uncertainty, for example, that associated with climate change, and the ability of water governance processes to account for the uncertainty, and interconnectivity between multiple ecosystems, social systems and action arenas (Bellamy *et al.*, 2002; Hirsch, 2006; Ison *et al.*, 2007; Pahl-Wostl *et al.*, 2007; Patterson, 2016).

Berkes and Folke (1998) have introduced social-ecological systems in the context of complex systems, linking ideas of the co-evolutionary nature and intertwining of biophysical and human systems (Norgaard, 1994). Ostrom (2009) proposed a framework for the analysis of social-ecological systems, presenting four core sub-systems: (1) resource systems, e.g. a designated protected park that may contain forested areas, wildlife, and water systems; (2) resource units, e.g. trees, shrubs and plants within the park, types of wildlife, and the amount and flow of water; (3) governance systems, e.g. the government and other organisations that manage the park, the rules related to the use of the park, and how these rules are made; and (4) users, e.g. individuals who use the park

for sustenance, recreation or commercial purposes (Figure 2.3), all of which are associated with second-order sub-systems, for example, system boundaries, collective choice rules, norms, performative measures, conflicts, networking, self-organisation, and spatial and temporal distribution. Growth in the concept of social-ecological systems has led to some progress been made with reference to the social dimension of ecosystem management (Cote and Nightingale, 2012), incorporating concepts of social capital, trust, social networks and social memory.

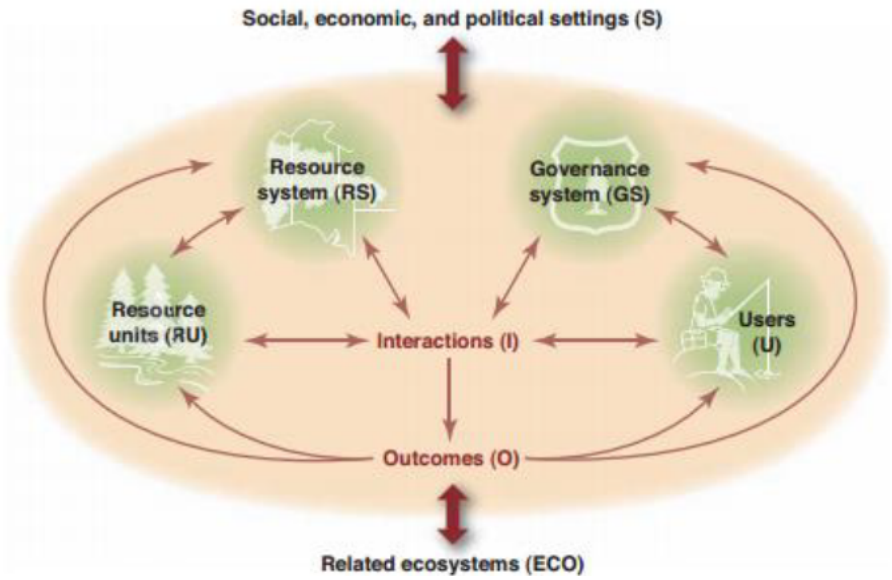

Figure 2.3: Framework for analysing social-ecological systems identifying the relationships between four first-level core sub-systems of a social-ecological system that affect each other (Ostrom, 2009).

Social capital has multiple conceptual and operational definitions (Neal, 2015). In some cases, social capital refers to social relationships (Neal, 2015), and in others, a phenomenon that arises from or encourages mixing between groups (e.g. bridging; Todd, 2012), the consequences of social relationships (e.g. trust), or refers to a phenomenon arising from or leading to cohesion within groups (e.g. bonding; Collins *et al.*, 2014). Putnam (2001) discusses the central idea of social capital as being one that networks and the associated norms of networks have value. He thus further supports the notion that there is no one single definition of social capital, and instead there are multiple dimensions of social capital. Not only do they have value for the people who are in them, but also have at least in some instance demonstrable externalities, with the presence of both public and private faces of social capital (Putnam, 2001). As such, social capital can

be thought of as a framework that assists with the creation of strong, dynamic and social networks developed through trust, reciprocity, knowledge exchange and connectedness, which together leads to successful collective action (Pretty, 2003), whereby social capital is a process and a resource (Neal, 2015).

Thinking of social capital as a resource has been suggested in the work of Midgley (2013). Drawing on a the notion of social capital developed by Granovetter (1973), Bourdieu (1986), Coleman (1988), and Putnam *et al.* (1993), among others, Midgley discusses how social capital emphasises the importance of social relationships in community life, and the importance of such relationships over individual experiences. Rather than the strength of communities residing in the capabilities of individuals, Midgley draws on the work of sociologists to talk about the importance of the intensity and durability of the social networks established between members of communities, with the networks being a resource, holding together and developing the community as a whole. Thinking of these ties as 'bonding' ties of communities, they are important in the creation of 'bridging' ties with other communities in being able to access resources beyond the communities boundaries, which are vital in promoting social and economic well-being (Midgley, 2013). Savage *et al.* (2013) build upon and support this notion, that along with economic and cultural capital, social capital is an important resource in one's social class.

Between-group relationships are viewed by some as a resource that facilitates one's access to other resources, such as information (Neal, 2015). Pretty (2003) lists the main benefits of social capital to and between stakeholders as: trust that others will behave in an expected manner; the reciprocity and ready exchange of knowledge and goods; behavioural changes that give people confidence to invest in a common good; and connectedness between local and distant groups. At the individual level, the social capital perspective argues that social ties can be used by actors to access or to control resources. At the group level, certain network characteristics such as density, provide a collectivity of actors with a cohesiveness that allows for collective pursuit of goals.

An important aspect of social capital is the process of social learning that is encouraged through the building of relationships and trust. In the context of water management, Pahl-Wostl *et al.* (2007: 2) state that, both in terms of its quality and quantity, social learning can be "analysed as a means of developing and sustaining the capacity of different authorities, experts, interest groups, and the general public to manage their river basins

effectively". Social learning was first made popular by psychologist Bandura (1977), when the term was used to refer to individual learning based on the imitation of role models. It is a fact that no stakeholder has all necessary information, legal competencies, funds, and other resources to manage a natural resource to satisfaction, therefore imposing the need for collaboration (Mostert *et al.*, 2007). To facilitate collaboration, stakeholders need to enter a long-term working relationship (Mostert *et al.*, 2007). Natural-resource management is a learning process (see, e.g. Holling, 1978), and requires the development of new knowledge, attitudes, skills and behaviours to deal with differences constructively, to adapt to change, and to cope with uncertainty (Mostert *et al.*, 2007). Social learning can be analysed as a process within a context (Craps, 2003; Ridder *et al.*, 2005; Pahl-Wostl *et al.*, 2007), including natural contexts such as geography, hydrology and ecology; and social contexts, including government systems, economy and culture (Mostert *et al.*, 2007).

The HarmoniCOP project comprises of 10 case studies of participatory river-basin management conducted to obtain detailed and contextualised information about social learning (Yin, 1993). The case studies covered a range of geographical, cultural, historical, and institutional contexts and included both completed and ongoing processes (Mostert *et al.*, 2007). For example, in the Dee basin, Scotland, it was realised early in the process the knowledge and expertise of farmers was needed (Mostert *et al.*, 2007). Therefore, demonstrating the importance of recognising and acknowledging that stakeholders have different geographical and issue-related areas of interest and they operate at different spatial scales (Mostert *et al.*, 2007).

In an attempt to blur the lines, and to reject the dualism between nature and society that characterises much of resource management theory, relational/hybrid systems of thinking in natural-resource management have been proposed (Rudy and White, 2013). For example, actor-network-theory (ANT) is used to represent this hybrid perspective of systems thinking, a concept that emerged from Science and Technology Studies in the 1980s (e.g., Callon and Latour, 1981; Latour, 1993; Callon and Law, 1997). ANT focuses on the facilitation of relationships in actor networks through non-human objects, for example, materials, technologies, objects, animals or ecosystems (Nimmo, 2011). In the context of water-resource management, applications of ANT have been demonstrated by Gooch *et al.* (2008) and Roy (2015). In their study, Gooch *et al.* (2008) applied ANT to the

studies of IWRM in the bordering areas of Vietnam and Cambodia, and Spain and Portugal; and Roy (2015) applied ANT to the study of city water supply governance in New Delhi, India. Of importance in both studies was the ability of ANT to focus on the material, as central in the resilience of networks relevant to governance of water resources. One of the critiques, however, in using ANT from a sociological perspective is the absence or inability to address power explicitly. Instead there is the assumption that all relationships in the network being studied are of equal importance in terms of the power they hold. ANT networks are made up of actants, both humans and non-humans, with no *a priori* assumptions about the causal efficacy of the actants, and involves breaking them down into subject/object dualism and analysing them symmetrically (Latour, 2005), along with ontological levelling (Eden *et al.*, 2000; Kirsch and Mitchell, 2004; Castree, 2012), ensuring equal agency to human and non-human actants.

Latour (2005) claims that class, race and gender are not important social structures, and social inequalities are due to network size and not the result of structural forces. Many scholars have challenged Latour's viewpoint, particularly critical political ecologists who instead analyse relations of dominance of social and political systems. It has been argued by Lave (2015) that the inconsistencies between ANT and the political ecology perspective, where the former assumes a flattened network approach, and the latter that recognises influence on structure on the production of inequalities, are too significant for ANT to be utilised in nature-society research. As regulated practice and form of governance always has a particular socio-historical and spatial context, this research will not adopt the network perspective that draws on ANT, recognising that the social is more than just networks, and that there are influences of wider social structures that play a part in producing and bounding networks. Acknowledgement is given that the wider social structures present in the system can have an effect on power dynamics, subsequently affecting inequalities in the system, that need to be considered in the research.

Other analyses of network structure considering governance and power relations are influenced by both governance and policy networks. Understanding of the network structure can be made in terms of "how direct relations are combined or arranged in a network" (Friedkin, 1981: 41); therefore, a reflection of patterns of interactions between human actors. Studies focusing on such relations often give attention and recognition to the presence of multiple institutions, groups and alternative actors within the network,

focusing on the presence and purpose of ties between them. Sandström (2008: 31) notes that in situations of interdependency, there does not always have to be symmetry:

> *"On the contrary, and emphasised by Lin (2001), the actors might be hierarchically related to one another depending on the resources they hold or can get hold of. The common misconception about networks, presuming a flat surface (by definition), must be dismissed. Although the actual differences in authority might not be expressed in or correspond to any formal organisational schedule, this should not lead to the interpretation that the distribution of power and influence is equal. On the contrary, this is rarely the case."*

As Castree and MacMillan (2001) discuss, ANT encourages us to imagine a world in which socio-natural relations are messy, complex and multiple. Despite being convinced by the core claims of ANT, Castree and MacMillan, however, remain uneasy about the implications of such claims in the construction of social-construction-of-nature arguments. They argue that ANT abandons some of the valuable elements of social constructionist thinking. First, ontologically, as stated by Laurier and Philo (1999: 1016) there is: "[T]he problem of installing a great indifference between the countless things of [the] world…which arises when they end up being portrayed as potentially all the same". In other words, the process of ANT results in the obscuring of differences between different things. It is something which in the context of this research, would be counterintuitive when the purpose of the research involves the exploration of the different stakeholders' involvement in water-resource management.

Alcadipani and Hassard (2010) offer further critique of ANT in their work, discussing four main criticisms suggested by Walsham (1997), which are: (1) it offers limited analysis of social structures; (2) it neglects issues of political bias and morality; (3) it fails to adequately conceptualise the differences between humans and non-humans; and (4) it has problems in the following of entities through the network analysis. Additionally, McLean and Hassard (2004) argue the ANT is associated with a number of controversies surrounding the inclusion and exclusion of actors and networks, the role of socio-technical privileging and status, as well as the distinction between agency and structure. Rather than encompassing and acknowledging opinions from all angles of for example an organisation, Star and Griesemer (1989) discuss how ANT has been accused of possessing a narrative that only accounts for the points of view of those at the top, including the

manager, entrepreneur or scientists' points of view, i.e. 'the so-called experts', resulting in the charge of managerial bias. Bearing all of these issues in-mind, and the desire to investigate and address power differences across the network, a network approach, over ANT is the method used in this research to investigate and analyse the network of stakeholders working in the Wear Catchment.

2.6. A Network Approach to Understanding Water-Resource Management Systems

Networks have become the focus and the foundation of governance with reference to 'wicked problems' associated with the understanding of managing natural resources, to analysis approaches and the conceptualisation of complexity involved in governance processes (van Bueren *et al.*, 2003; Carlsson and Sandström, 2007). Governance processes take place in governance networks, involving public policy making and implementation via a series of relationships between governments, businesses, and civil society actors (Klijn, 2008). Therefore, there is a clear link between understanding governance processes and governance networks through which processes occur. A network approach can be thought of simply as an organisation, individual, etc. creating strategies to increase their connections with others, i.e. the network. By having an awareness of the interests and roles of each of the entities, along with awareness of the strengths, weaknesses and purpose, and goals, relationships can be forged between different members, thus enhancing and building the network. Regardless of what the groups comprise, be it organisations, groups of individuals, etc., they are encouraged to cooperate and collaborate with various types of other individuals with the aim of promoting their group to grow stronger, more stable and more competitive. An important aspect of the network approach is not just including similar groups, but including many groups from government, to businesses, and members of the public.

A key component of the network perspective in social-ecological systems is the bringing together of scholars from the social sciences, in relation to social interactions, for example, together with ecological networks, such as food webs (Dunne *et al.*, 2004). Janssen *et al.* (2006) explore different types of social-ecological networks and have proposed that the network perspective can be used to evaluate issues related to resilience and adaptive governance with reference to the management of natural-resources and combined with

social and ecological network perspectives can provide an understanding of heterogeneity and dynamism in networks. With reference to water, Stein *et al.* (2011) show through the concept of networks the interconnectivity present between hydrological and governance systems, which albeit being present are not always effective, for example, in the joining up of thinking in how to manage water resources, or how modelling of the physical environment can be used to inform expert decision-making. By thinking about the network as a whole, rather than a series of sub-networks, there is potential for improvements to be made to the current ways of working in the context of water-resource management.

With reference to studies of networks in natural-resource management, there is a divide between those studies that consider both social and ecological networks (e.g. Janssen *et al.*, 2006), and those that predominantly focus on network analysis of social interactions. The majority of studies conducted focus on the latter, concerned with understanding and analysing institutional networks or describing governance networks. In such studies a key interest is understanding the network structure and its components, focusing on the interrelations between the nodes, and the context created through node interactions, for example, the relationships between micro-scale interactions and the grander-scale structure present in the network (Janssen *et al.*, 2006).

Several studies have highlighted the need to focus on the links between network structure and its components, for example, the features of the network that represent and enable the creation of social capital, or the importance of the presence of brokers in the network, i.e. those acting as advisors in the network (Tompkins and Adger, 2004; Newman and Dale, 2005; Bodin *et al.*, 2006; Koppenjan, 2008). Amongst others, Bodin *et al.* (2006) have used SNA to expose the social relations in the network. SNA is focused on the ties among groups, be they people, organisations or countries (de Nooy *et al.*, 2011). The ties combine to form a network that can subsequently be analysed (de Nooy *et al.*, 2011). SNA is based on the idea of seeing social relations in formal terms as patterns made up of points (nodes) and lines (ties), that can be analysed (Crossley *et al.*, 2009). Underpinning the analysis is social network theory, a conceptual framework that is built on mathematical graph theory, depicting interrelated social agents or actors, be they people, organisations or teams, etc. as nodes (vertices) and their relationships as lines (ties) drawn between them (Borgatti and Foster, 2003; Madey *et al.*, 2003; Borgatti and Ofem, 2010; de Nooy, 2011).

The ties depict, for example, the transfer of resources, transactions, communication, authority and power (Springer and Desteiguer, 2011). The typology of relations studied in SNA can be grouped into five categories (Borgatti and Ofem, 2010):

1. Similarities
    a. Location – e.g. same spatial and temporal space
    b. Membership – e.g. same clubs, same events
    c. Attribute – e.g. same gender, same attitude
2. Social relations
    a. Kinship – e.g. mother of, sibling of
    b. Other role – e.g. friend of, student of, competitor
3. Mental relations
    a. Affective – e.g. likes, hates
    b. Cognitive – e.g. knows, knows about, sees as happy
4. Interactions and transactions – e.g. talked to, advised, helped, harmed
5. Flows – e.g. information, beliefs, money

Analysis of networks is typically conducted using quantitative interpretations of the relations shown in the network. SNA is not just about looking at the 'numbers' identifying who has the strongest link to whom in numerical terms and is also about looking at the structure of the network, seeing who has links to whom, interpreting what the numbers actually mean. Scholars in the field of SNA, such as Wasserman and Faust (1994) and Degenne and Forsé (1999) recognised the link between social network structure and actor behaviour. Core principles of SNA are based on social theoretical understanding of a number of factors, such as, how and why people communicate; as well as, graph theory providing a formal understanding of the network structure, standardised descriptors of measures of betweenness, centrality, reachability and density, referring to the number of nodes in the network, ties between the nodes, and the existence of clusters and sub-groups, allowing for comparisons to be drawn between networks. Granovetter (1973) discusses a way of understanding network configuration in terms of looking at the strength of ties in a network, and the effect that different strength ties based on factors such as trust, closeness, and frequency of exchange between actors, can have on the functionality of the network.

To depict the structures of ties, a sociogram is produced (de Nooy *et al.*, 2011). A sociogram brings together different data sources at the collection stage, standing at the interface between different methods and the analysis stage. An important aspect of the network concept is that the ties between nodes are not treated in isolation to one another, and instead are considered together as they link up to form paths, providing a mechanism through which nodes may affect one another indirectly (Borgatti and Ofem, 2010). From the mapping of relationships, the patterns that emerge can be analysed in terms of their quality, the positions of actors within the network and overall structure of relationships (de Nooy *et al.*, 2011). One possibility is to see how well-connected the overall network is, and whether certain actors emerge as ones linking different parts of the network together. In instances where the network holds cliques or isolated groups, there is a possibility to recommend network restructuring. Koppenjan (2008) states effective networked systems incorporate mutual trust, reciprocal relations, and strong cooperation. This may be the case in some network systems, however, mutual trust, reciprocal relations and strong cooperation might not all be necessary. Taking for example, the point on reciprocal relations, it may not be necessary for the network entities to have reciprocated relations, if communication is only one-off, and not long-term.

SNA has been found to be a particularly useful tool in mapping important knowledge relationships between people and/or departments, improving collaboration, knowledge creation and knowledge transfer in organisational settings (Cross *et al.*, 2000). Overall network properties, for example, the number of ties compared to the total number of possible ties, gives an insight into the possibility for collaboration in the network, as well as the structural cohesion of the network (Olsson *et al.*, 2004). The analysis of sociograms allows for managers to visualise and understand the relationships that can either facilitate or impede knowledge creation and transfer, for example: how does information flow within an organisation? To whom do people turn to for advice? Have sub-groups emerged that are not allowing for the sharing of what they know as effectively as they should? (Cross *et al.*, 2000). Using SNA, it is possible to glean quantitative information from the network using network measures, which can be used to quantify the relationships between actors in the network.

Bodin *et al.* (2006) focus on the balance of network measures, specifically, density, reachability, betweenness and centrality; and the relation of these measures to the

characteristics of the network, which in a natural-resource management context help to facilitate structures that are favourable to adaptive co-management of resources. From the mapping of social networks, it is possible to understand how interdependencies, associations, relationships and interactions shape society. To assist with understanding such features of a network, there are several things suggested to look for, including (Cross *et al.*, 2000):

1. Bottlenecks – central nodes that provide the sole connection to different parts of the network;
2. Number of links – insufficient or excessive links between departments that must coordinate effectively;
3. Average distance – degrees of separation between all pairs of nodes in the group, the shorter the distance, the more accurate and timelier the transmission of information;
4. Isolation – people who are not well integrated into the group, therefore representing untapped skills and a high likelihood of turnover;
5. Highly expert people – not being utilised appropriately; and
6. Organisational sub-groups or cliques – can develop their own subcultures and negative attitudes toward other groups.

In organisations, a significant yet often overlooked component of people's information environments is comprised of relationships that they use in the work place to acquire information knowledge (Cross *et al.*, 2000; 2001). As Cross *et al.* (2002) discuss, if you put an organisational chart in front of most of the employees in an organisation, they will tell you that the lines only represent some of the way that work gets done. Often informal interactions which do not appear on such charts are in fact more reflective of how work happens in organisations rather than relationships established within the formal structure ranked for example by hierarchy (Brass, 1984; Cross *et al.*, 2002).

Formal structures, are intentionally designed organisations, such as governmental and non-governmental institutions and universities, linked to larger institutional arrangements (Prell *et al.*, 2010). Informal structures on the other hand, are social networks, such as families and friendship groups, and are based on communication contacts individuals have (Prell *et al.*, 2010). Informal interactions, however, often remain invisible or at least only partly understood by managers, and is a growing problem

because of de-layering of organisations, virtual work and globalisation (Cross *et al.*, 2002). Prell *et al.* (2010), investigated the differences between formal and informal structures in relation to stakeholder perceptions. Research on social structures suggests that both formal and informal structures influence individuals' thoughts, values and behaviours (Prell *et al.*, 2010).

Relationships between members of a network can be characterised by direction (represented by arrows in a sociogram, Figure 2.4), and intensity (with the relative strength of ties, indicated by the thickness of the lines in the sociogram, Figure 2.4) (Mueller-Prothmann and Finke, 2004). Cliques and clusters are sometimes apparent in the network, whereby sub-sets of members form dense connections and develop cohesive sub-groups of the network (members 3, 4, 5 and 6 in Figure 2.4) (Cross *et al.*, 2002; Mueller-Prothmann and Finke, 2004). Structural holes in the network may be present, as in many cases, networks are not only clustered into cohesive sub-groups, but are instead split into loosely coupled or independent components, whereby not all possible connections are present, these are structural holes (members 13, 14 and 15 in Figure 2.4) (Mueller-Prothmann and Finke, 2004). Persons of pivotal significance in holding together components of the network are called cut-points or bridges (Mueller-Prothmann and Finke, 2004). Bridges are central nodes that provide a singular connection between different components within the network (Mueller-Prothmann and Finke, 2004). Cut-points build bridges between sub-groups, groups which would have otherwise been cut-off and split into separate, unconnected components of the network (member 2 in Figure 2.4) (Mueller-Prothmann and Finke, 2004). Some members in the network are important actors in many clusters, and are simultaneously involved in various areas, areas are known as hubs (Kleinberg, 1997; Rosen, 2000).

Comparisons can also be drawn between formal and informal structure in an organisation. As Brown and Duduid (1991) discuss how ethnographic studies of workplace practice have shown the ways people actually work differs from the ways described in organisations' manuals, training programmes, hierarchical organisational charts, and job descriptions. As shown in Figure 2.5, members of department c have built dense connections with each other, and have developed a strong cohesive sub-group independent of the remainder of the network, since all its members are connected to one another (Mueller-Prothmann and Finke, 2004). Ultimately, "who you know has a

significant impact on what you come to know" (Cross *et al.*, 2002). Clusters are a feature of specific interest to network analysts, because they are important features for allowing for understanding of the behaviour of the whole network (Mueller-Prothmann and Finke, 2004). It has been found organisational clusters or components can develop their own "sub"-cultures and attitudes, often towards or against other groups (Mueller-Prothmann and Finke, 2004). In some instances, clusters or components have also gained power of the overall network (Mueller-Prothmann and Finke, 2004). Cook *et al.* (1983) argue network centrality does not necessary equate to power exchange in networks.

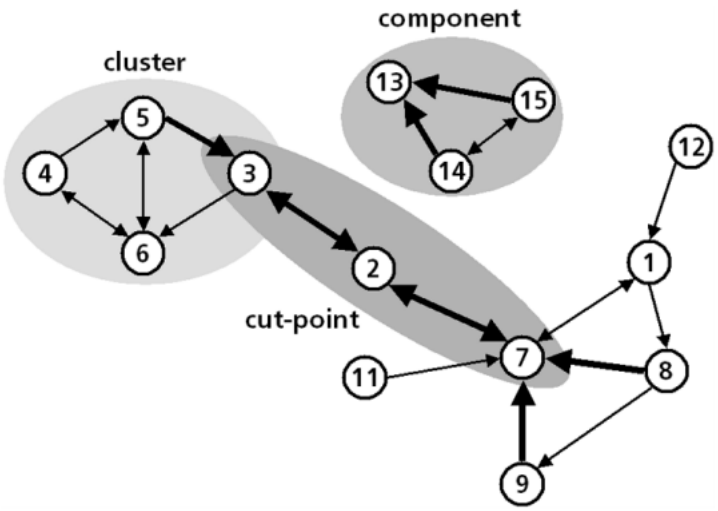

Figure 2.4: Network members and their relationships (Mueller-Prothmann and Finke, 2004).

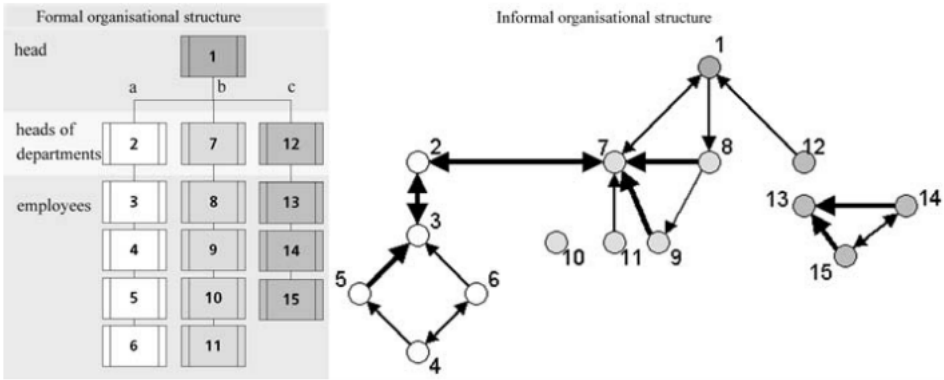

Figure 2.5: Formal versus informal structure in a research organisation (Mueller-Prothmann and Finke, 2004).

As shown in Figure 2.5, organisational networks often have expert networkers present. For example, member 7, who is head of department b, has high expertise and is a contact person in his team, as shown by degree centrality (Mueller-Prothmann and Finke, 2004). Degree centrality is a measure of incoming (in-degree) and outgoing (out-degree) connections that an actor in the network has (Mueller-Prothmann and Finke, 2004). Popularity of a member is shown by their in-degree. Individual members with many ties in the network are assumed to be those with high levels of expertise. Too many linkages, i.e. an excess, can indicate that the member is being put under stress and being overloaded, for example, member 7 in Figure 2.5. Member 2 (Figure 2.5) is head of department a. Despite being considered an expert, they are not a popular contact. Instead of direct communication between member 2 and their department, member 3 communicates knowledge from member 2 to members 4, 5 and 6. Member 3 is the 'agent' for member 2. Ultimately, without the link between member 3 and member 2, members 4, 5 and 6 would not receive information from the rest of the organisation.

Silent experts can also be found in organisational networks (Mueller-Prothmann and Finke, 2004). For example, expertise of member 13 is only passed onto their direct colleagues (Figure 2.5). Cross *et al.* (2002) found in their study that many senior people became distant from and uninvolved in day-to-day workings and operations in their group. One reason for their expertise only being passed to direct colleagues is due to the fact their expertise is not known outside of their department, i.e. not across the whole organisation (Mueller-Prothmann and Finke, 2004). Member 13 here has insufficient links, and members of the network in such a position are likely to not be well integrated into knowledge flows. Therefore, highly expert people are not being appropriately utilised (Cross *et al.*, 2002). On the other hand, experts in a network may have highly specialised knowledge. For example, member 8 in Figure 2.5, they have a relationship across formal hierarchies with member 1 (Mueller-Prothmann and Finke, 2004).

In some instances, much of the expert communication can be focused around leaders or heads of departments as in the case of the organisation represented in Figure 2.5. Narrow expert communication can be problematic in that, for example, if member 7 leaves, it could result in a great loss of expertise, creating a structural hole, splitting parts of the network into unconnected components (Mueller-Prothmann and Finke, 2004). In a network, cut-points represent bottlenecks which are critical to the flow of knowledge in

the network (Cross *et al.*, 2002; Mueller-Prothmann and Finke, 2004). On the one hand, too few links can be problematic especially if key members leave, but equally too few links can potentially lead to inefficiency in the network with regards to the flow of knowledge (Cross *et al.*, 2002; Mueller-Prothmann and Finke, 2004). Enablers allow for links to be made between different sub-groups within the network, and can also allow for the facilitation of knowledge flows between departments, and external organisations (Mueller-Prothmann and Finke, 2004).

Study of the relationships between network structures and governance structures is essential to interpret and analyse natural-resource management systems using a systems perspective, expressing the importance of structure, networks and power relations. As Kahler (2009: 3) states, "network analysis has too often obscured or ignored questions of network power and power within networks, portraying networks as an antithesis of the hierarchical exercise of power that lies at the core of familiar political institutions".

2.6.1. Examples of Using a Network Approach to Understanding Water-Resource Management Systems

A number of studies have been conducted linking SNA and natural-resource management, including water-resource management. Sandström and Rova (2009) carried out quantitative analysis of social networks in fish-management areas in Västerbotten, Sweden, drawing links between network structure and management performance. They found network density impacts collective action of those involved. Prell *et al.* (2009) conducted research in The Dark Peak area of the Peak District National Park, UK, giving an example of how network analysis can be applied in exposing the dynamics of stakeholder networks. Combined with SNA, Prell *et al.* (2009) used stakeholder analysis to identify key central and marginalised groups in networks. By doing so, the value of the research was that it could potentially be used to change working practice, better balancing integration and participation of stakeholder groups. The research also provided better awareness and understanding of knowledge exchange between stakeholders in a collaborative partnership working together to manage the National Park.

Fliervoet *et al.* (2016) used SNA to challenge and investigate the movement to the equitable partnership role of governance organisations, focusing on floodplain management in the Dutch Rhine delta. Focusing on relationships between

flood-protection organisations and nature management, they demonstrate the consequences of removing the central actor in the management network, highlighting the dependence of stakeholders on central actors despite the so-called shift in governance following their removal.

Stein *et al.* (2011) used SNA in the Mkindo catchment in Tanzania to empirically map social networks between actors to assess the effects of networks on capacity to govern water. Findings of their study indicate that informal networks with village leaders acting as links between different groups are important but are not acknowledged in current governance systems. In this context, SNA could be used to inform the governance system, placing greater value on informal water management networks.

These studies demonstrate the importance of networks as modes of governance, giving rise to the term 'governance networks. Governance (see Section 2.2) networks include collaborative or participatory aspects, which become informally or formally institutionalised by going beyond the *ad hoc* (Newig *et al.*, 2010). Torfing (2005: 307) define governance networks as:

> *"(1) relatively stable horizontal articulations of independent, but operationally autonomous actors who (2) interact with one another… (3) within a regulative, normative, [and cognitive] … framework that is (4) self-regulating within limits set by external forces and which (5) contributes to the production of public purpose [such as natural resource sustainability]."*

It is important to note that governance networks do not all have the same function, and can take many forms, not always labelled in the same way (Torfing and Sørensen, 2014). Sometimes government networks are referred to as think tanks, public boards and committees, collaborative arenas, etc. Governance conducted in networks makes a difference to individual and collective learning, and so the functioning of environmental management practices (Newig *et al.*, 2010). However, Montenegro *et al.* (2014: 111), claim:

> *"Governance in the form of self-organised networks doesn't seem to occur through planning. These networks are self-forming and, based upon observations, are gaining more strength and autonomy over time (Sørensen & Torfing, 2005). [...] The more we*

know about networks, the better we understand governance dynamics and its relationships with government, informal mechanisms, and private actors. Hence, we believe that qualitative research is essential for understanding some of the questions related to governance networks."

Ultimately, governance networks are a desired state in the context of environmental management (see Section 2.2). SNA and social-ecological network analysis are beneficial in working towards such a state, in that they can be used so as to raise questions about network configuration, creation, maintenance, utility, stability and resilience. The use of SNA provides the opportunity to be able to understand, compare and evaluate the roles stakeholders play in the governance of water resources, and thus their contribution towards achieving the goals of the WFD, for example. By identifying, visualising and assessing the roles of stakeholders in their current state it offers a baseline of assessment from which future scenarios of change can be investigated, for example, what would happen if a stakeholder was removed from the network, or if a stakeholder was no longer able to contribute the same number of resources to projects as they are at present? Such future scenarios of change can be investigated using ABM.

2.7. ABM of Water-Resource Management Systems

Before going into detail about ABM, it is important to set the context of what a model is. A model is a representation of a researcher's understanding of a given situation. Models are defined by the way they function, along with the use as a tool for exploring (Harvey, 1969). In recent years, computation has become the main mode for model creation. Digital computation led to the 'quantitative revolution in geography' in the 1950s and '60s (Barnes, 2004), with a favouring of mathematical modelling, but was criticised for its inability to recognise the complexity of the real-social world (Gilbert and Terna, 2000; Clifford, 2008). Ostrom (1990) developed and introduced the alternative 'third symbol system' involving simulation. Simulation is a type of modelling that allows for deeper exploration of the phenomenon of interest. The aim of simulation modelling is to gain understanding of the operating processes and mechanisms of a system, unlike statistical models that just recreate patterns of correlation (Gilbert and Triotzsch, 2003).

Modelling offers a valuable tool of potentially being able to explore the dynamics and mechanisms through which certain outcomes of a system may be produced. Through

modelling it is possible to experiment with different behaviours and different combinations of behaviours to observe potential changes in outcomes within the system being considered (Millington and Wainwright, 2017). Model outputs can be used as discursive material, e.g. with stakeholders, regarding the state of a particular system and possible future changes if behaviours and interactions were to be enacted in reality, and therefore offer a starting point in deliberations.

Simulation is a key base of ABM. Simulation introduces a new way of thinking about social processes of simple behaviours and their emergent properties (Gilbert and Triotzsch, 2003). Ideas surrounding behaviours and emergent properties arise from complexity theory (Waldrop, 1992; Kauffman, 1995). Complexity theory looks at non-linear systems and interactions, producing unpredictable effects and patterns (see Section 2.5 on systems). Early simulation in the 1960s was largely based on system dynamics. The earliest models focused on studies of large-scale systems, for example, predicting the future of the world economy (Meadows *et al.*, 1974).

Another early simulation strategy was microsimulation, focused on population changes based on probabilities (Orcutt *et al.*, 1986; Gilbert and Triotzsch, 2003); but has been criticised because of the lack of interactions between individuals. In the 1980s and '90s, the idea of putting the 'agent' in modelling emerged (Gilbert and Triotzsch, 2003). In physical sciences developments surrounding the cellular automata model were made, made popular by John Conway in the Game of Life model, in which cells/individuals live or die depending on rules reflecting processes such as overcrowding and reproduction (Epstein and Axtell, 1996). Cellular automata models are made up of discrete cells that represent the population and environment, and each time step changes between two states occur, in the case of the Game of Life model, living or dying, based on information about the state of neighbouring cells (Crooks and Heppenstall, 2012). The idea of such models is to create a representation of systems-level behaviour through the use of simple, local behavioural rules. Widespread application of the modelling approach has occurred, however, in such models agents are limited in space, or interact separately with their environment, something which in geography is of interest in the context of spatial social-ecological systems, and is what agent-based models came to represent (Batty *et al.*, 2012).

Agent-based simulation is one type of computer-simulation framework that has been used by some geographers to explore the intermediate complexity of the world (Bithell *et*

al., 2008 as cited in Millington and Wainwright, 2017). The agent-based framework can be used to flexibly represent our conceptual models of discrete, multiple, multi-faceted and heterogeneous agents (be they humans, organisms, institutions or any other entity that pursues a goal), and their interactions and relationships between one another and with their environment, through space and time (Railsback and Grimm, 2012; Wilensky and Rand, 2015; Millington and Wainwright, 2017). In their simplest form, an agent is an individuated object with unique defined attributes (e.g. location, sex, aspirations), capable of carrying out context-dependent functions that may result in changes to their own attributes and of others (e.g. whether or take a job or not depending on whether you like where you are currently working) (Miller and Page, 2007; Railsback and Grimm, 2012; Millington and Wainwright, 2017).

The properties of the agent-based simulation frameworks allow us as researchers to represent the world as being composed of autonomous individuated objects (agents) with causal powers that may (or may not) be triggered depending on the circumstances of the object (Millington and Wainwright, 2017). The agents therefore can be thought of as providing a means of representing our abstracted understanding of human agency (Millington and Wainwright, 2017). The combination of an agent-based conceptual model and computer code used in creating the model for simulation is referred to as ABM. Three broad styles of ABM exist and are detailed in Table 2.1. Like all models, ABMs can be used to explore theories and their possible implications, to attempt to understand how particular theories play out, test scenarios of change, and to assist in decision-making (O'Sullivan *et al.*, 2012).

The foundations of agent behaviour are determined by a set of rules, which are typically derived from published literature, expert knowledge, data analysis or numerical work. One ruleset can be applied to all agents to categories of agents or each agent can have its own unique set of rules in the model. Rules are typically based on 'if-else' statements (i.e. the condition of the statement is true or false), whereby the agents carry out an action once a specified condition is met.

Table 2.1: Classification of ABMs - three broad styles (O'Sullivan *et al.*, 2012).	
ABM Style	**Description**
Simple abstract models	Focus is on exploring the collective implications of individual-level decision-making.
More-detailed models – real-world setting	Locates virtual model agents in a representation of the real-world setting of interest. Typically operates at the regional or landscape scale, e.g. land use or land cover change in the context of climate change scenarios.
"Realistic" representations	Realistic representations of both the geographical setting and the processes unfolding in that setting. Driven by concerns of policy- and decision-makers. Focus on urban, economic and demographic management applications.

At the most basic level, an agent is "an object with defined attributes capable of executing functions autonomously" (Millington and Wainwright, 2017: 5). Further to this, Jennings *et al.* (1998: 276) define an agent as "a computer system, situated in some environment that is capable of flexible autonomous action in order to meet its design objectives". Agents are entities that pursue a certain goal, examples often including, but not restricted to, organisms, humans, businesses, institutions (Railsback and Grimm, 2012). Crooks and Heppenstall (2012) list a number of common attributes of an agent in the context of ABM in geographical studies, as follows:

1. Autonomy: Agents are free to interact with other agents. There are no central controls on agents, with the exception of the influence of social norms and institutions that have accumulated as a result of previous agent interactions (Epstein, 2006).
2. Goal directed: Each agent has a set of goals to fulfil.
3. Reactive: Agents have some sense of their surroundings and can react to changes in their environment.
4. Bounded rationality (one of a number of modelling approaches, including satisficing, heuristics, etc.): Agent's behaviour is grounded in the rational choice paradigm (Axelrod, 2007), and to move towards their desired goal, agents make

decisions that are adaptive and inductive, but remain bounded by the use of local information to inform their decision-making.

5. Interactive: Agents are able to communicate with other agents.
6. Mobility: Agents are free to move through the space defined in the model.
7. Adaptive/learning: To simulate a learning process, agents can be programmed to change their state based on previous states.

In addition, Hamill and Gilbert (2016) also list agents' characteristics under four key headings:

1. Perceptions: Agents can see other agents in their neighbourhood and their environment.
2. Performance: Agents can act, such as moving and communicating with other agents.
3. Memory: Agents can recall their past states and actions.
4. Policy: Agents can have rules that determine what they do.

In the 1960s and '70s, Schelling was one of the first to apply the concept of ABM in social sciences, with the writing of 'Models of Segregation' in 1969, 'On the Ecology of Micromotives' in 1974, and 'Dynamic Models of Segregation' in 1971. Segregation models created by Schelling focus on the preference of agents' neighbours being the same 'colour' as them, moving accordingly until they are settled in their preferred location, surrounded by those who are similar, resulting in the creation of segregated neighbourhoods. Through experimentation with ABM, it opened up new possibilities of being able to investigate social phenomena, and emergent patterns based on simple behavioural rules. Or as Epstein (2006: 12) puts it, a "powerful new way of doing empirical research".

Early application of ABM in the context of social-ecological systems is demonstrated by the SugarScape model (Epstein and Axtell, 1996) that comprises an environment in which sugar is spatially distributed, a resource which the agents use as food. Agents move around the model in an attempt to access the resource in order to thrive and remain alive; and in doing so allowing for the observation of emergent behaviour of the modelled society through simple behavioural rules. The SugarScape model provides a means of being able to understand and investigate the ecological carrying-capacity of the land, and the movement of the population around the space.

Social modelling such as ABM have begun to be used in environmental disciplines, with the intentions of being able to describe and predict the way people (or actors, referred to herein in the context of ABM as agents) are likely to behave in response to different stimuli given various decision rules (Prell *et al.*, 2007). Models are an abstracted and simplified description of a process, event or object (Bandini *et al.*, 2009; Wilensky and Rand, 2015), and can be used to provide a purposeful representation of some real system to advance our understanding of how that system works (O'Sullivan *et al.*, 2012; Starfield *et al.*, 1990 as cited in Railsback and Grimm, 2012). Researchers construct and use models to solve problems or to answer questions about a system or class of systems (Railsback and Grimm, 2012). Models are no longer built for production *per se*, but are built as much to inform general scientific inquiry, in addition to debate between stakeholders over future scenarios of change (Epstein, 2008; Bandini *et al.*, 2009). Figure 2.6 shows one example of the process involved in the creation of a model, beginning with the formulation of the research question, the hypotheses to be tested, and the model structure, implementation of the model to analyse and test the hypotheses. It is important to note that Figure 2.6, although quite akin to the standard model of the hypothetico-deductive modelling approach in science, not all ABMs necessarily follow this approach. With regards to this research, hypothesis testing will not be incorporated, owing to the nature of this research, involving the use of ABM to test a range of future scenarios building upon SNA.

Central to the understanding and application of ABM are two concepts: complexity and emergence. Complexity is a property of a system, in which elements of the system are deeply interconnected. The removal of one element in a complex system can have the potential to dramatically change the functioning of the system (Miller and Page, 2007). Within a complex system, behaviours emerge from lower-level component activities, or local agent interactions, the lower-level components being individual agents who are part of the complex system (Epstein, 2006; Miller and Page, 2007). To navigate through the complex system, agents need to have adaptive behaviour (Sawyer, 2005). If emergence is considered to be true, then by understanding lower-level components, one can start to uncover and investigate the development of higher-level components of the system.

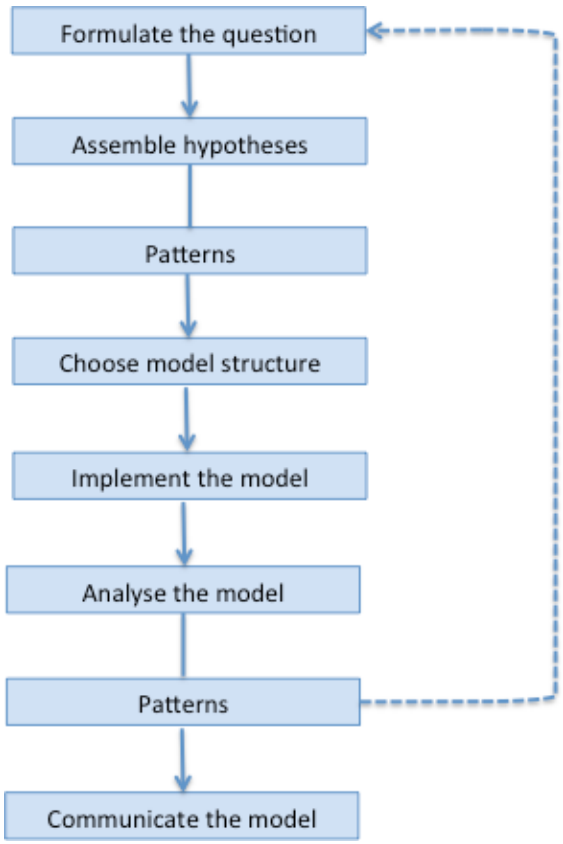

Figure 2.6: The modelling cycle - ABM (adapted from Grimm and Railsbeck, 2005 as cited in Grimm and Railsback, 2012).

ABMs can be used in a generative sense, through the process of modelling of a group of heterogeneous agents placed in an environment, to observe the emergent patterns of interactions between them and their environment according to behavioural rules. Gilbert and Terna (2000) think of ABM as a 'third way of doing science', different from induction and deduction, but including both aspects, induction and deduction at various stages in the modelling process; therefore disagreeing with Grimm and Railsback (2012) and their approach to ABM. Used in a variety of ways, ABM can prove useful in theory building to hypothesis generating and testing, prediction, and development and testing of possible future scenarios of change (O'Sullivan *et al.*, 2012).

One must remember when using ABM, there is the issue of realism. Like all models, ABMs are also an abstraction of the real world, and are only an interpretation of reality. Reality that can be constructed and modified by the researcher (O'Sullivan *et al.*, 2012). Due to the abstraction of reality of ABMs, they are often critiqued for tending away from the heterogeneity and rich diversity visible in socio-ecological systems (Batty *et al.*, 2012). Millington and Wainwright (2017) critique the ABM 'SugarScape' for its simplicity and for

being epistemologically 'thin'. ABMs have also being critiqued for making no contribution to sociological theory, missing out on inequality, power and privilege, things which are all important in an institutional context (Goering, 2006). However, by combining ABM with other methods as demonstrated in this research, such as interviews, information on power can be investigated.

When combined with empirical data, the value of ABM is enhanced (Zellner *et al.*, 2014). As Chattoe-Brown (2014) discusses, ABM can integrate data from experiments, interviews and surveys; therefore, bringing together qualitative and quantitative research techniques. In quantitative data collection, analysis and numbers are used, and in contrast qualitative data collection operates on narratives or texts, including interviews, documents and field notes (Chattoe-Brown, 2014). By using data about the individuals or their environment, the ABM can be used as an exploratory tool with respect to the other level. In cases using data about both the individuals and their environment, the full distinctiveness of the ABM methodology can be revealed, supporting the argument that ABM can be used to integrate different types of data (Chattoe-Brown, 2014). If the ABM can represent empirically plausible individual behaviour, giving rise to simulated aggregate data which is the same or like the real data, then it is possible to conclude that an association of the data has been found, which can be explained (Chattoe-Brown, 2014). Therefore, the hypothesis is that the simulated data look like the observed data is because the real social processes unfold like the processes being simulated in the model.

However, there is often a critique of incompatibility, of qualitative versus quantitative, if ABM is viewed as the former in the research. It can be epistemologically difficult to translate qualitative data into coded rules, variables and numbers required for ABM. However, Yang and Gilbert (2008) have challenged this critique, stating there is nothing inherently quantitative about ABMs, and so no incompatibilities of the sort exist, and instead is down to mere translation issues (Agar, 2003). ABM can be used to bring together and combine qualitative and simulation approaches, allowing for iterative knowledge and theory creation. As Bohensky (2014: 2) states: "A great advantage of agent-based models is that they do not intend to predict future outcomes but stimulate thinking and initiate dialogue critical to addressing the challenges that are faced in this arena." This is something that is particularly important in the context of this research with it being intended that findings from the ABM will be passed onto stakeholders working in

the Wear Catchment to inform their discussions of future changes to the management of water resources. One thing that stakeholders could potentially use from the research findings is why do some stakeholders work well with some, but not others? Is it due to their working proximities within the catchment, i.e. do they focus on similar problems but not in the same areas?

Using ABM, Neal and Neal (2014) simulated neighbourhoods and neighbourhood social network formation to explore if community-diversity dialectic emerges from two principles of relationship formation: (1) homophily, and (2) proximity. Homophily is the "tendency to associate with familiar others" (Neal and Neal, 2014: 2). Prell *et al.* (2010) describe homophily as a double-edge sword. On the one hand, individuals who are similar have more mutual understanding, and are therefore more likely to be able to communicate implicit knowledge more easily (Raymond *et al.*, unpublished manuscript as cited in Prell *et al.*, 2010). However, due to the exchange of knowledge being predominantly and more likely to occur between similar individuals, new information may not reach dissimilar groups or individuals (Granovetter, 1973). Homophily can therefore present a problem when stakeholders come together, to collaborate to problem solve and develop management options (Prell *et al.*, 2010). Rouchier *et al.* (2014) build a theoretical framework to detect the conditions which give rise to social influence which enables persistence of a shared opinion between members of the same organisation over time, whilst accounting for membership turnover. To understand the transmission of, e.g. opinions in an organisation from generation to generation, requires uncovering the mechanisms of social influence among members in the organisation (Rouchier *et al.*, 2014), providing insight into why some individuals interact and why others do not, and therefore, a basis of what changes need to, or could be made to encourage interactions between those who do not communicate, leading to changes in working practices, capturing more opinions and thoughts, etc.

2.8. Bringing together SNA and ABM

Many social science models require an underlying network model. Therefore, there is potential to bring together ABM with SNA, with ABM simulations sometimes referred to as social agent-based simulations (SABS) (e.g. Koźlak and Zygmunt, 2013). The key difference between SNA and SABS is that SNA is based on the analysis of the whole of society, whereas, in SABS the model, the description of local interaction between agents

within the society of interest is given, and the model is subsequently used in the design of the simulation tool which makes it possible for the analysis of social behaviour (Koźlak and Zygmunt, 2013).

There are four basic types of models of networks: (1) regular lattice, (2) small-world, (3) scale-free, and (4) random (Hamill and Gilbert, 2009). The setting of the ABM is what can be referred to as a social map (Hamill and Gilbert, 2009). Like the geographical map does for places, showing how they are distributed and linked, the social map does the same for people, showing the links, or ties between them. Therefore, when two individuals are located close together on the social map, they are close socially, i.e. the closer the agents, the stronger the tie. The bringing together of the two methods has been demonstrated by Singer *et al.* (no date). They used ABM to investigate friendship in social networks. The model proposed was to understand the structuring of social networks within a fixed setting, one example being a university. Initially the agents in the model had no connections, and each time step, two agents were chosen to form an acquaintance. Encounters at the beginning were random, however in time, preferential selection occurred, with some agents forming connections, i.e. friendships, based on the frequency of encounters between individuals and mutual interest.

ABM offers a tool for exploring network dynamics, focusing on the creation and dissolution of network ties between agents. Combining network science and simulation models (in this case, ABM), offers a means of being able to understand how networks form and evolve, and how features of those settings, such as diversity and segmentation impact on the process. According to Chattoe-Brown (2014), the operation of ABM without any data is like abstract mathematics.

In the context of socio-ecological systems, ABM can be used to assist in investigations and understanding of decision-making in complex systems (Smajgl *et al.*, 2011). Focusing on the context of management, ABMs can be used to facilitate analysis of complex human-environment interactions (Janssen, 2002; Barreteau *et al.*, 2003; Gotts *et al.*, 2003; Bousquet and Le Page, 2004). Specifically in water-resource management, Izquierdo *et al.* (2003) state that ABM is an appropriate way of addressing integrated water-management issues due to:

1. The importance of agent heterogeneity (Axtell, 2000);
2. The importance of adaptation;
3. The crucial role of the environment concerned;
4. The importance of the existence of social networks; and
5. The importance of focusing on relationships between individuals' behaviour and attributes, and the global properties of social groups (Gilbert and Triotzsch, 2003).

As detailed by Mason (2006), the mixing of methods in research offers potential for generating new ways of understanding the complexities and contexts of social experiences, as well as enhancing our understanding and capacities for social explanation and generalisation. By combining SNA and ABM, and using qualitative data throughout, offers an innovative way of addressing the major challenge of finding an effective method to analyse complex water governance arrangements, in particular the social dimension, as detailed by Pahl-Wostl (2002). Ultimately, the mixing of methods allows for 'thinking outside the box', along with enhancing capacity for thinking beyond the macro and the micro (Mason, 2006), which will reveal additional information about interactions and behaviours, offering greater insight into the social dynamics between organisations, for example.

Of great importance in the context of this research, the mixing of methods also allowed for enhancing and extending the logic from qualitative explanation from the interviews with stakeholders, using the information gleaned from the interviews to explain the network of stakeholders in the Wear Catchment, and in the informing of the behaviours of agents representing the stakeholders in ABM. Ultimately, the mixing of methods allows for a complex problem to be seen from multiple angles, and parts which can be brought together to produce a fuller, or more robust picture than what would otherwise be possible using singular methods (Mason, 2006).

2.9. Summary

Chapter 2 starts by giving an overview of the concepts of governance and management with the focus being on the environment, providing detail on how the two concepts come together, and are applied in water-resource management. Focusing on water-resource management, a review of the participation of stakeholders is given, detailing how the concept of a stakeholder, and what constitutes a stakeholder in the context of water-

resource management, drawing comparisons between experts and non-experts, and how a stakeholder can be defined. From the critique of what constitutes a stakeholder, detail is given on how participation has emerged as an approach to enhance natural-resource management, drawing on examples from the involvement of the public. Three key principles in the management of natural resources, namely, integration, adaptation and collaboration are introduced, including definitions and how they come together, feeding into the WFD.

Chapter 3 – Context & Data-collection Methodology

This chapter provides an overview of the data-collection methodology of this research. As detailed in the introduction, exploring the state of UK water-resource management in this research is being conducted at the catchment-scale in relation to stakeholder involvement, specifically focusing on a case-study perspective of the Wear Catchment (Yin, 1993). Firstly, detail is provided on the current state of the Wear catchment in terms of current water-resource governance, followed by an overview of the data collection methods been used in this research. Then, detail is given on the recruitment of participants from the Wear Catchment for this research.

A combination of methods was used in this research for data collection in order to explore fully the state of the catchment-wide water-resource management system, and to understand the connections and interactions between stakeholders. The philosophy underpinning the use of a combination of approaches is that of Berkes *et al.* (2003: 8) who states that: "a complex social-ecological system cannot be captured using a single perspective". The combination of methodological approaches utilised comprise of a survey and interviews to gather multiple perspectives and voices, and SNA, thematic analysis of interviews and ABM as means of analysis of the data.

3.1. Context: The River Wear Catchment

To investigate the current state of collaborative water-resource management in the UK, the River Wear Catchment was chosen, due to its locality and the ongoing need for continued and improved water-resource management within the Catchment. The Wear Catchment has been part of the CaBA since 2011, with the Lower River Wear been one of the 25 pilots for the trialling of the management approach between 2011 and 2013. The Lower River Wear pilot was one of 10 pilots led by the Environment Agency. The Lower River Wear was chosen as a pilot due its array of complex pollution problems with 23 of its 25 waterbodies failing the objectives of the WFD at the time of the rolling out of the pilots, combined with a lack of collaboration between stakeholders within the catchment.

The CaBA has now being rolled out across the whole of the Wear Catchment, and the transition from the pilot in the Lower Wear to catchment-wide has led to changes been made amongst stakeholders, reflecting on their learning, interaction and participation in water-resource management (Tindale, 2018). New partners joined existing members to

roll out the scheme fully, reflecting on progress and in the implementation of new working practices in managing water resources in line with achieving good status in line with the goals of the WFD.

3.2. Characteristics of the River Wear Catchment

The upper parts of the catchment are predominantly grouse moorland, along with areas of lead, limestone and coal that have given rise to the historic mining legacy of the catchment. Moving down through the catchment to the lower reaches, the land is mainly used for arable farming, residential areas, and larger urban centres. In the lower catchment, the River Wear and its tributaries are used for a number of recreational activities, including angling and rowing. Owing to the rich mining heritage of the catchment it has been subject to diffuse acidic heavy metal pollution from minewater discharges (Neal *et al.*, 2000). As a result of mining cessation in the north-east along with the installation of small-scale passive treatments such as reed beds, and larger-scale minewater pumping stations across the catchment, it is that over the last 40 years, a reduction in minewater pollution has occurred (Neal *et al.*, 2000). Despite such an improvement, however, there is still need for continued management across the catchment.

In line with the WFD, the Environment Agency divided the Wear Catchment into 64 management units (waterbodies), and now in the second management cycle of the WFD (2015 to 2021), the aim is to achieve good status in each of them. In 2016, around 91% of the waterbodies in the catchment were below good status according to the Environment Agency (Environment Agency, 2017), with the water industry being responsible for the majority of failures. Even though there have been improvements to treatment works, sewage discharges into the waterbodies are still problematic. This is along with abandoned mines and quarrying, as well as industry, waste treatment, domestic use, local and central government and land management practices, both agricultural and rural contributing to water quality issues (Environment Agency, 2017), there is much work still to be done. There is also the challenge of identifying the cause of failing status of some waterbodies, with the causes still being unknown by the Environment Agency who are the responsible regulatory authority. In light of the current state of the waterbodies of the Wear Catchment, it highlights the need for continued and improved coordinated and collaborative action between stakeholders in water-resource management.

Since the introduction of the WFD, water-resource management has been coordinated and implemented at the catchment-scale. With the CaBA, catchment partnerships have been developed to coordinate the implementation of collaborative catchment-management, with the intentions of localising coordination of priorities and activities regarding the management of water resources. In line with the Lower Wear Catchment being a pilot catchment for the CaBA, the Wear Catchment Partnership was established in 2011, with the Environment Agency appointed as catchment-host. The Environment Agency was responsible for coordinating meetings, inviting participants to meetings, and leading on the writing and production of documents and funding applications.

Within the Environment Agency a Catchment-Coordinator was also appointed, with the responsibility of overseeing everyday workings and decisions made in the management of water resources in the catchment through the CaBA. The Environment Agency was able to use its existing resources and contacts, along with the Catchment-Coordinator's knowledgeability, and the willingness of key partners to invest and participate in the new working practices to guide and motivate the aim of working together, resulting in the creation of a positive partnership (Tindale, 2018).

During the two-year pilot scheme from 2011 to 2013, the Wear Catchment Partnership invited participants to a number of stakeholder meetings, with the aim of creating a Catchment Action Plan, identifying water management issues and potential collaborative solutions to them (Tindale, 2018). A development group of key stakeholders was formed to assist with achieving the aim of the partnership, with members including the Environment Agency, Northumbrian Water, Durham Wildlife Trust, the Wear Rivers Trust and Durham University; all of whom were involved in close working to research, deliberate and create the Catchment Action Plan (Tindale, 2018). Responsibilities of the development group also involved the organisation and coordination of joint action as well as data collection, sharing events, consultation and meetings. Activities of the development group were supplemented by wider stakeholder meetings, allowing for the gathering of opinions, evidence, priorities and information from affected and interested parties, all of which went into the Catchment Action Plan informing and coordinating new efforts with existing efforts, and with the resources and skills available.

Following the pilot scheme, the Wear Catchment Partnership entered into an action implementation phase, expanding to incorporate the rest of the Wear Catchment (see Figure 1.1, Chapter 1). Over the pilot, the Wear Rivers Trust became joint host with the

Environment Agency, and later became the lead host, which achieved the vision of having local presence and an NGO as host, moving away from central government leadership of the CaBA. Today the Wear Catchment Partnership remains dedicated to protecting and improving the Wear Catchment through the implementation of the CaBA and is made up of over 14 stakeholder groups including public, private, and voluntary and charity sectors. The intention is for the partnership to continually develop over time, including a broad membership comprising organisations and individuals who represent the widest range of catchment interests possible.

Core participants of the Wear Catchment Partnership along with the Wear Rivers Trust are currently Durham County Council, Durham Heritage Coast Partnership, Durham University, Durham Wildlife Trust, the Environment Agency, Groundwork North-east and Cumbria, Natural England, North Pennines Area of Outstanding Natural Beauty Partnership, Northumbrian Water, and Sunderland City Council. To address two priority projects in the catchment, two sub-delivery partnerships have been formed, the Greening the Twizell Partnership, and the Heritage Coast Partnership, as well as the Topsoil Project group (see Chapter 1). As detailed in Chapter 4 (SNA) these three groups were used to inform stakeholder sampling involving the recruitment of participants to partake in this research.

3.3. Gaining Perspectives of Stakeholders

To explore the catchment-management system of the Wear and the connections and interactions between stakeholders, a combination of methods was employed in this research. Data collection comprised the use of a survey and interview approach, subsequently analysed using SNA, thematic analysis of interviews, and ABM.

Stakeholders involved in water-management practices are at the centre of this research. It is through their actions and interactions that practices of water-resource management are enacted in the everyday. Through feedback, discussions and deliberations of the stakeholders, it is possible to analyse their experiences and outcomes of current practices. The following sections describe and justify the processes of questioning and interviewing stakeholders and analysing their views and opinions to gain in-depth perspectives of the current state of collaborative water-resource management in the context of the Wear Catchment.

3.3.1. Data Collection: A Combined Survey and Interview-Based Approach

The purpose of qualitative research is to understand and gain information on the ways people experience events and processes, and how people see and view places differently as part of a fluid reality (McGuirk and O'Neill, 2016). The fluid reality being constructed as a result of multiple interpretations that is filtered through several frames of reference and systems to make sense of the meaning of the information (Mcguirk and O'Neill, 2016). Surveys offer a means of being able to gather information on characteristics, behaviours and/or attitudes of a population on a given topic by administering a set of questions or a questionnaire to a sample population (Parfitt, 2005; McLafferty, 2010; Mcguirk and O'Neill, 2016).

Ultimately, producing a well-designed survey requires a great deal of reflection by the researcher, as suggested in an array of literature (Mcguirk and O'Neill, 2016). The focus of the survey must be related to the aim and objectives of the research being conducted, as well as relating to the researcher's critical understanding and examination of relevant processes, relationships and concepts of the topic being investigated (Mcguirk and O'Neill, 2016). One guiding principle suggested by Babbie (2003) in the design of survey questions is to ensure that the target population will be able to answer the questions, i.e. they have sufficient knowledge to answer them, and conversely not be led by the wording of the question to answer in a way that confines any existing prejudices of the researcher.

Despite no two surveys being the same, with each survey having its own unique topic and sample population, the process of conducting survey research involves a common set of steps as detailed by McLafferty (2010), upon which the surveying approach used in this research will be based. The first step is to design the survey, whereby the researcher needs to develop a questionnaire that will allow them to achieve the goals of their research and that is clear and easy for respondents to understand. Secondly, the researcher needs to decide on how they are going to administer the questionnaire; and thirdly, identifying the sample population, i.e. the number of people the questionnaire is going to be given to, and who these people are going to be. Guidelines for the design of a survey are as follows (McLafferty, 2010):

1. Basic principles to achieve
    a. To keep the questionnaire simple

    b. To define the terms clearly, and
    c. To use the simplest possible wording
2. Things to avoid
    a. Long, complex sentences
    b. Two, or more questions in one
    c. Jargon
    d. Biased or emotionally charged terms, and
    e. Negative words

In a questionnaire, questions can either be open-ended, providing the researcher with qualitative information, or they can be fixed-response questions that are often easier for the respondents to answer owing to a set of possible responses being available to them. The latter work well when the questionnaire has to be self-explanatory, i.e. when the questionnaire is a self-administered survey as opposed to an interview questionnaire (McLafferty, 2010). Fixed-responses are also easier for the researcher to interpret and analyse, albeit they lack the detail, richness and personal viewpoints from the respondents (McLafferty, 2010) and you can only find out what you put into the fixed responses.

One of the most critically important steps in constructing questionnaires is pre-testing or pilot-testing the survey on a small group of people to check the questions, responses (if appropriate), layout and instructions (McLafferty, 2010; Mcguirk and O'Neill, 2016). Therefore, allowing for the identification of any flaws in the questionnaire that are not obvious to the researcher, and the questionnaire can be subsequently modified accordingly before sending it out to the intended sample population.

A number of strategies exist for conducting questionnaire surveys: face-to-face interviews, telephone interviews, postal surveys, drop-off and pick-up questionnaires, and internet surveys. Postal surveys are self-administered by the respondents, the questionnaires are posted out to them, and then posted back once completed. With postal surveys there is no time pressure for the respondents, allowing them to complete them at a time that is convenient to them (McLafferty, 2010). However, the response rate is often low, with typically less than 30% returning them, which may not be representative of the target survey population (McLafferty, 2010). An advantage of internet surveys is that they can often have the same format as postal surveys but cost less to administer making use of websites such as 'Survey Monkey', 'Google Forms', or 'Online Survey'. Once completed,

responses are immediately available to the researcher, which is faster than having to wait for responses to be posted back. Internet surveys also provide access to geographically dispersed populations, and can be used to reach immobile groups (Madge and O'Connor, 2004 as cited in McLafferty, 2010). Owing to these advantages, the survey in this research was administered online, as detailed in Section 3.2.3.

The sample of people to whom the questionnaire is administered to is key, as who responds to the survey has a key impact on the results. A sample is selected to represent some larger population of interest be it a group of people or institutions or organisations that are the subject of research. Following the approach of McLafferty (2010), the first step is to identify the sampling frame, i.e. those individuals who have a chance to be included in the sample (Fowler, 2008 as cited in McLafferty (2010), and the second step is whether to select individuals using random or stratified sampling, the latter allowing for even coverage of the population in the sampling frame. Ultimately, the larger the sample, the more precise the estimates of population characteristics, providing more information on the topics covered in the survey, but with proportional increases in the time and effort required by the researcher to collect and analyse the results.

As detailed by McGuirk and O'Neill (2016), when conducting surveys it is essential to inform participants of the research being conducted and how information they provide will be used, and therefore it is essential to obtain informed consent, as well as managing privacy and confidentiality of the participants. Participants were informed through an overview of research about the project intentions and the use of data they provided, so as to allow them to make an informed decision about participating (Dowling, 2000), and with this information was an informed consent sheet (Appendix A), that the participants had to agree or disagree to, with an agreement allowing the participant to continue and gain access to complete the survey. Participants were made aware that although their own name would not be identifiable, the name of their organisation would be used along with their words, so as to contextualise the knowledge and information provided in their responses; and is something which all participants agreed to be acceptable.

Interviewing was used to follow-up the collection of survey data, to expand and elaborate on survey responses. Data from the survey provided a framework for the interviews, with the identification of key themes, concepts and meanings to be further discussed, teased out and expanded upon by participants (see McGuirk, 2004). Interviews allow for focus on the complex behaviours and motivations of individuals (Dunn, 2016), in this research

those individuals representing stakeholder organisations, giving the chance to investigate diversity of meaning, opinion and experiences (Valentine, 2005). Interviews give stakeholders the opportunity to use their own words and to describe and discuss their experiences and activities in a way meaningful to them (Rubin and Rubin, 2005; Presser and Sandberg, 2015). Using narratives constructed by the interviewees (Kvale and Brinkman, 2009) and information gleaned from interviews, it was possible to build a picture of the stakeholders' worlds with reference to water-resource management activities in the Wear Catchment, and to compare and analyse experience diversity between stakeholders.

Interviews were designed to be semi-structured, allowing for the conversation to unfold in a way led by the interviewee (McCracken, 1988). To extract information from individuals, and to collect novel data to gain an understanding of their views and opinions semi-structured interviews are typically used (Kitchen and Tate, 2000; Dunn, 2005; 2016; Valentine, 2005; Longhurst, 2010). Semi-structured interviews allow for verbal interchange between the interviewer and interviewee, with the interviewer attempting to elicit information by asking pre-determined questions, allowing the interview to unfold in a conversational manner to explore issues that are important, whilst ensuring a freedom to let the interviewee guide the interaction and influence the way issues are addressed (Cook and Crang, 1995; Dunn, 2005; 2016; Valentine, 2005; Mayan, 2009; Longhurst, 2010). According to McCracken (1988: 9) there is "no other instrument of enquiry that is more revealing" than the semi-structured interview. Owing to the high flexibility and balanced structure, the semi-structured interview could be the most important way of conducting an interview, in order to gather high-quality data.

The use of semi-structured interviews also allows for an insight into the personal opinions of individuals to be collected on topics of a more sensitive nature, which they may have not thought to have or wanted to include in their survey responses, or indeed could not include because of the closed nature of the survey questions. Unlike surveys, in which the questions and responses (in the case of closed questions) are determined prior to the survey being distributed, therefore giving no scope for opportunities for the respondent to define the focus of the research or to contribute to things otherwise that are not covered in the survey (Rubin and Rubin, 2005). Interviews may also give the interviewer a chance to gain knowledge and familiarity of activities and opinions that may be otherwise difficult to access, understand or experience by an outsider, with regards to

reflections on past events, or future hopes, feelings, and opinions on relationships and/or experiences (Valentine, 2005). The interpretation of experiences expressed by the stakeholders is based on understanding that humans are conversational beings (Silverman, 2010). The language they use although transient, does in fact represent the reality of the stakeholders themselves, and to attempt to understand the views of the stakeholders as the interviewees as consistently as possible with their meanings (Silverman, 2010).

An advantage of interviews over other types of data collection is their "complexity capturing ability" (McCracken, 1988: 16). As interesting themes emerge throughout the interview, the interviewer can explore them, which is particularly useful for unanticipated issues (Valentine, 2001). One way of overcoming the inability of the respondent to add additional data not covered by the survey was to give respondents the opportunity to participate in a follow-up interview following the completion of the survey. Owing to the personal contact being made with them, participants often feel valued, and appreciate the opportunity for time to talk on a one-to-one basis; something which with surveys alone is not possible.

As with all methods, there are limitations associated with the collection of data using interviews. The opinions generated in the interviews are very much dependent on the context and setting in which the interview takes place. As Denzin (1978) discusses, there are often difficulties associated with reaching the private worlds of people's experiences, and is dependent on the interview situation, for example, how well the interviewer and interviewee know one another, determining the level of trust between them. In some instances, interviewees provide answers that they think they should rather than what they want to provide, because they want to befit their role and situation keeping in line with a somewhat stereotyped role following the rules of normal social interactions, keeping to their professional status, rather than giving their own personal opinions (Singleton and Straights, 1999).

Being familiar with the interviewee at least provides some grounding of trust, and by having a structured setting whereby the interviewee knows the purpose of the interview, and has some control over the content, i.e. via the semi-structured approach, can be used to overcome some of the difficulties. By been clear prior to the interview that responses were to be kept anonymous, only referring to the names of organisations, and stored securely, it was intended to encourage the interviewees to speak openly and confidently

without fear of what they said being sourced back to them, which in an organisational and departmental setting could lead to job insecurities, and unnecessary stresses, which may have lowered the willingness of people to participate in interviews. Therefore, a full ethical approval including confidentiality agreements was covered in the research process, both as a requirement by the University, and Departmental Ethics Committee to protect the rights of the participants, and how the data and information they provided was to be used ethically and adhere to ensuring anonymity throughout the research process and beyond.

Owing to the fact that some topics of discussion tended towards difficulties and problems of communication and relationships with individuals and groups in the Wear Catchment, which may have professional consequences, it was important that protection measures were in place. Again, participants were provided with a consent form prior to the interview, including a short overview of the research, and the intended use of the interview data in the context of the research.

An important consideration to be made when conducting interviews, as with all qualitative data collection is to have an awareness of the potential impacts and consequences that could arise, either directly or indirectly affecting those involved (Dowling, 2000). It is therefore necessary to carefully monitor researcher conduct and actions in relation to the participants of research and the groups involved whose behaviour and working practices are being analysed, being respectful and aware of researcher and participant actions and conduct (O'Connell *et al.*, 1994; Armitage *et al.*, 2009). The core principles underpinning ethical research relate to the fair distribution of benefits and burdens, minimising harm, be it physical, emotional, economic or environmental harm, whilst considering the welfare, beliefs, heritage, rights and customs of the research participants, and all others involved (Hay, 2010).

In the case of all participants, they were all representing an organisation, and were aware of their position of speaking on behalf of themselves and of their organisation, and their responsibility for doing so and adhering to the message of their organisation. In some cases, participants had multiple identities, representing a number of groups and/or organisations, and so spoke in more than one capacity. Some participants exercised their control over information they had revealed. For example, information that was still not yet confirmed for definite, on a project etc., or if they had revealed information on a personal opinion or a comment about a particular situation and wished for such

information not to be shared directly in the wider research. The reassurance that was given was that in the case of such information, it would not be used directly. Participants who held a managerial role, or a position in a relatively small organisation or team, for example, also expressed concern that others would be able to identify them. In all instances participants were reassured of the anonymity of the research process, which regardless of position is the same for all participants. By reassuring participants, they were happy to converse and felt more at ease and secure and in control of the information they shared and how it was going to be used in this research. Additionally, by allowing participants to choose the location of the interview it was intended that they would feel more comfortable during the interview. Participants were asked if they would like to come to the University, where I would book a small room in the department, or if they would prefer to a book a room at their workplace or find a mutually convenient location to which I would travel.

As with other methods, such as surveys, interviews are much reliant and limited on people's time and ability to recall. Rather than interviews being unbiased reports on what actually took place, interviews are instead verbal narratives of what the respondents think took place, i.e. what they can remember (Valentine, 2001). When interviews delve into things that happened in the past, for example, a particular situation such as a meeting, the interviewer is reliant on the ability of the interviewee to remember, therefore, adding potential for inaccuracies in the data (Singleton and Straights, 1999). To counteract these potential biases and inaccuracies, Miles and Huberman (1984) suggest the triangulation of methods. A triangulation of methods was, however not used in this research, owing to the fact that the survey responses were given to the participants to be used as a prompt and basis for their thoughts and responses during the interview; therefore, accounting for at least some of the potential inaccuracies that may arise without having such information at hand, such as mismatch between what they said in their survey to what they said in their interview.

3.3.2. Identifying Stakeholders and Inviting Participation

In this research a self-completion survey was used (Knoke and Yang, 2008). Starting with the Wear Catchment Partnership, the stakeholders involved were contacted for the initial drive for participants to partake in this research. Other stakeholders involved in water-resource management in the Wear Catchment beyond those involved in the Wear

Catchment Partnership were identified through attendance at meetings including the Topsoil Project, the Greening the Twizell Partnership, and the Heritage Coast Partnership. Stakeholders were then asked to give their recommendations of other groups and/or individuals who could also be asked to complete the survey. In instances where recommendations were given, groups and individuals (on behalf of their organisation and/or department) were approached directly via email. As described in the work of Valentine (2005), a snowballing approach was employed in order to distribute the survey to new individuals and groups, and continuing until no new people or groups were identified.

Unfortunately, some stakeholder groups were unresponsive to requests to complete the survey. These were farmers and local community groups, and organisations and departments working on the peripheries of water-resource management in the Wear Catchment, who despite working with other stakeholders directly involved in the catchment-management did not see the need or have the desire to partake in this research. The reasons for lack of response however cannot be certain. Unresponsiveness may have been due to lack of familiarity of the topic area of the project, as well as judgement about relative (un)importance of taking part in the research whilst working to meet their own priorities and work activities. Unresponsiveness may have been to competing workloads, a high volume of surveys to complete, and therefore the inability to complete them all, as well as relating to the wider issues of the organisations' intellectual and professional engagements to which they are exposed. Ultimately, reasons as to why some groups were unresponsive can only be speculated, and it is important to note the reasons listed are simply suggestions and by no-means the actual or definite reasons for unresponsiveness.

In total 31 people completed the survey from 11 organisations, from public, private and voluntary and charity sectors. Of the 31 people who completed the survey, 13 also agreed to be interviewed. These individuals all play some role in the management of water resources across the Wear Catchment, either through protecting, maintaining, monitoring or utilising the water environment. The organisations and groups, to whom the participants belong are:

1. Environment Agency
2. Northumbrian Water
3. Wear Rivers Trust

4. Durham County Council
5. Durham Heritage Coast
6. Durham University
7. Sunderland City Council
8. North East England Nature Partnership
9. Stanley Town Council
10. Exhibit "A"rt
11. North Pennines Area of Outstanding Natural Beauty (AONB)

These organisations are all involved in or related to decision-making and/or action in water-resource management activities in the Wear Catchment. Ultimately, each of the stakeholders have the potential to influence the social-environmental system within the catchment, albeit some more than others depending on their authority, power and position in the network. Within the network generated in this research, there are multiple types of actors, who have multiple values, knowledges, opportunities, behaviours and positions with regards to the water governance activities.

3.3.3. Content and Focus: Survey and Interviews

The survey was used to elicit information on the network of stakeholders working in water-resource management in the Wear Catchment, giving insight into who works with whom and the interactions between the stakeholder organisations. In the first section of the survey, participants were asked to identify up to ten organisations including the names of departments where appropriate, with whom they work with in water-resource management in the Wear Catchment. The number of organisations participants could list was limited to ten, so as to avoid participants writing an exhaustive list, which may in some instances have included organisations with whom they have rarely had any contact with but have listed them, simply 'just because' to make their list of contacts longer, with stakeholders appearing for no reason other than to fill in space. Limiting the number of stakeholders who could be listed also forced the participants to reflect on those most important to them. For each of the organisations, participants were then asked the primary benefits that they receive from each of them. Responses for the primary benefits were provided as opposed to allowing the participants to write their own responses, so as to allow for comparisons to be drawn across the survey responses. Participants were

then asked to rank the relative amount of contact they have with each of the organisations named. The purpose of each of the sections in the survey is listed in Table 3.1.

The survey was distributed using an online survey tool, 'Online Surveys' (formerly Bristol Online Surveys, BOS), which is free to use through the University's license. The use of the online tool meant the survey could be sent to a large number of people for free, and the survey results could be automatically collated and downloaded to be analysed. With the survey being accessed using a website address, it meant that the survey link could be easily passed onto other groups and individuals, and therefore employing the snowballing approach with ease (Valentine, 2005). Survey respondents were asked at the end of their responses to provide their email address if they were happy to be interviewed.

In this research, interview questioning was ordered yet flexible, so as to allow the conversation to evolve naturally, with questions being developed *in situ* based on the content and tone of the conversation (Dunn, 2005; 2016). To be able to draw comparisons between interviews, a prompt sheet was used as a guide, containing themes and questions to be covered and asked, but otherwise the interview was tailored to the individual circumstances of the situation. An important aspect of the interviews was to recall and go over the interviewees' survey responses, to gather further data on the relations between organisations working in water-resource management in the Wear Catchment, to understand and explore the dynamics of stakeholder behaviour, and to capture the collaborations between them, or lack thereof.

When conducting the interviews in this research, the interviews were recorded using a combination of audio recording and note-taking (Longhurst, 2010; Dunn, 2016). Audio recording allows for a full focus on the interaction with the interviewees, allowing for a natural conversational interview style reducing the pressure to record all the interviewees' words in a notebook, and giving more time to organise the next prompt or question (Longhurst, 2010; Dunn, 2016). Because an audio recorder does not keep a record of non-verbal data, non-audible occurrences such as body language and gestures these were noted. Note taking also offered a backup in case of technical failure. In two instances in this research, recording using an audio device was not possible due to the location of the interviews been in public areas, note taking was therefore used.

Table 3.1: Purposes of survey sections.

Section	**Purpose**
Identification of organisations you work with	With reference to the analysis of the data, the organisations listed by respondents were used to form the basis of the SNA (see Chapter 4), in the creation of the nodes of the network diagram.
Identification of the primary benefits that you receive from the organisations	With reference to SNA, the purpose of asking respondents to state the primary benefits from the organisations they have listed was to provide analysis of the ties between the nodes of the network, for example, which stakeholder organisations share data with whom, etc.
Ranking of the amount of contact with organisations	By asking respondents to rank the stakeholder organisations they listed in the survey relative to one another, according to the amount of contact they have with each of them, the ties in the social network could be scaled accordingly.

3.3.4. Positionality

It is important aspect of research to consider researcher positionality, which forms part of the understanding of and interpretation of knowledge that emerges from interviews (Skelton, 2001). Positionality affects how the researcher reflects on their own identity as a researcher and as an individual, defined by their gender, class, race, nationality, politics, history and experiences, shaping the type and form of research that they conducted and the interactions they had with their participants (Schoenberger, 1992; Valentine, 2005). As argued by Schoenberger (1992), knowing about the position of the researcher, it can

lead to significant findings about the research process and the nature of the research conducted.

By employing self-scrutiny of one's own positionality, aspects of positionality can be explored (England, 1994). For example, my own experience of researching has been influenced by partaking in stakeholder meetings within the Wear Catchment, including the Wear Catchment Partnership, the Topsoil Project, the Greening the Twizell Partnership and the Heritage Coast meetings, in which I have been an active participant in presenting my research to stakeholders, and in the case of Topsoil, representing the group at international conferences. Representation on behalf of the Geography Department and Durham University at the meetings and conferences has led to the building of trust and familiarity with a number of stakeholders in the Wear Catchment, and the building of trust with stakeholders beyond these groups. It can be assumed that by becoming as much of an insider as possible allows for the building of trust in the research process (Kvale and Brinkman, 2009).

Attendance at stakeholder meetings has given insight into the ways of working of the organisations involved, including how they interact with one another around the table in meetings, and more specifically how and who they communicate with. In the meeting environment it was possible to observe the behaviour of individuals, developing an understanding of their role in the management of water issues, and the balancing of their work and priorities for the meeting with various other deadlines. From minutes made at meetings, I was able to gather understanding of the communication outside of the meetings, and the roles played by the various stakeholders in data collection and acquisition, for example. Although somewhat challenging at times as a 'newbie', it was through the positioning myself as both an active member of stakeholder meetings, contributing my knowledge and expertise where possible, I was able to develop relations with stakeholder organisations, as well as an awareness of the roles of organisations in water-resource management.

3.4. Summary

Chapter 3 has introduced and detailed the context and data-collection methodology used in this research. A detailed description of the case study location for this research, the Wear Catchment, deemed to be an appropriate place to investigate the current state of water-resource management in the UK. In the description of the Wear Catchment a review

of the implementation of the WFD in the catchment was given, detailing the CaBA, and the transition from a pilot phase into the full roll out of the approach across the whole of the catchment. The remainder of the chapter focused on the approach to data collection, combining a survey and interview to gather information from stakeholders working in the Wear Catchment regarding the involvement and roles of other stakeholders with whom they communicate and work alongside in the management of water resources. Included with the description of the data collection methods is detail on the approach used in the identification and recruitment of research participants, as well as recognition and reflection on potential ethical implications associated with the collection of data, and researcher positionality.

Chapter 4 – Social Network Analysis

The specific focus of this chapter is on the SNA of the stakeholders working in water-resource management in the Wear Catchment. By conceptualising the water-management system as a social network, in-depth SNA can be used to investigate and assist in understanding of the configuration of the network, focusing on the links and interactions between stakeholders, and the relative position of stakeholders in the network. The overall intention is to provide a basis for the assessment of the current state of collaborative water-resource management with respect to the CaBA in the Wear Catchment. At the centre of this research is the process of gaining perspectives from stakeholders involved in water-resource management practices. Focusing on the actions and interactions of the stakeholders makes it possible to gain insight into everyday working practices, and through their feedback, discussions and deliberations it is possible to analyse their working practices, and to highlight the strengths and flaws of water-resource management.

Underpinning the analysis is social network theory, a conceptual framework which is built on mathematical graph theory, depicting interrelated social agents, be they people, organisations or teams, etc. as nodes, and their relationships as links drawn between them (Borgatti and Foster, 2003; Madey *et al.*, 2003). The links depict, for example the transfer of resources, transactions, communication, authority and power (Springer and Desteiguer, 2011). SNA is the tool used to analyse the connections between the people and organisations, and the tool available for modelling, visualising and analysing interactions between them (Springer and Desteiguer, 2011).

The first step in SNA is to identify the network, and the second step is to collect social interaction data, i.e. on transactions, communication, authority, power and kinship (Springer and Desteiguer, 2011; Lienert *et al.*, 2013). From the mapping out of relationships, the patterns that emerge can be analysed in terms of their quality, the positions of actors within the network and overall structure of relationships. One possibility is to see how well-connected the overall network of stakeholders is, and whether certain actors emerge as ones linking different stakeholder groups together. In instances where the network holds cliques or isolated groups, there is possibility to advise of network restructuring.

4.1. Background to SNA

To reiterate from Chapter 2, SNA can be used to model, visualise and analyse the connections and interactions between entities represented as nodes, be they people, organisations or departments, etc. (de Nooy *et al.*, 2011; Springer and Desteiguer, 2011). A key advantage of SNA is that it can combine quantitative and graphical data, allowing for descriptions of the interactions of individuals, groups, etc. that are both ethnographically grounded and quantitatively rigorous (Borgatti and Ofem, 2010). SNA provides several possibilities to link theories of social movements and collective action to environmental management, to study the participation and cooperation of a diversity of actors (Sylvère and Emmanuel, 2017).

Since the focus of SNA in this research is on relationships between nodes, it is relationships between them that must be captured in data collection (Borgatti and Ofem, 2010; Edwards, 2010). To capture such relations, two major strategies have been developed (Borgatti and Ofem, 2010; Edwards, 2010):

1. Whole- (or full) network analysis involving the selection of a set of nodes and then measuring the ties between all the nodes within the sample; and
2. Egocentric (or ego network) analysis involving the selection of a set of focal nodes (egos) from a population, and then asking the individual egos to give the names and characteristics of the alters (individuals, organisations, departments, etc.) they relate to, along with the relationships with each of them.

In whole-network analysis, the population of nodes selected by the researcher typically corresponds to some kind of group, such as a self-identified group, or an externally determined group (Borgatti and Ofem, 2010; Edwards, 2010). Despite the word 'whole' being used, the network collected using the whole network approach may be interconnected, made up of a series of disconnected nodes fragmented into many components, with no types of ties being measured in the study between them (Borgatti and Ofem, 2010).

In many ways, egocentric analysis is similar to whole network analysis to execute (Borgatti and Ofem, 2010). However, rather than beginning with the whole population, the first step to select a sample of respondents (Borgatti and Ofem, 2010). Egos are the interviewed in a two-stage process (Borgatti and Ofem, 2010):

Stage 1 – Apply what is known as a name generator, consisting of a range of network questions, e.g. names of people you work with. The questions are typically open-ended, giving multiple opportunities for the names of, for example, individuals in a person's life (alters) to emerge. From these findings a roster of names is developed.

Stage 2 – Using the roster of names, the second stage involves questioning, known as the name interpretor stage. The individual respondents are systematically asked about the nature of their relationship with each of the alters listed on the roster. The data are then interpreted using a network-based theoretical framework.

The attraction of researchers to use egocentric research over whole-network analysis is the ease of the collection of data (Everett and Borgatti, 2005). Dissimilar to whole networks, ego networks have a constrained and simple structure which delivers the benefit of simplicity in the data collection (Everett and Borgatti, 2005).

Social networks can be analysed at three levels: the node level, the dyadic level and the network-level. At the node-level, researchers focus on where each individual node is positioned in the overall network structure. One of the most commonly referred to node-level concepts is centrality (Cambridge Intelligence, 2014), which is a family of concepts that describe node position. At the dyadic-level, researchers focus on the properties of pairs of alters in the network. Examples of dyadic measures include geodesic distance and structural equivalence. At the network-level, researchers focus on the network structure, looking at, for example, density and centralisation. Structure is an important factor to consider in SNA, for example, teams with the same composition of member skills can perform differently depending on the relationship patterns between the members. At the individual node-level, a node's outcomes or characteristics depend on part on its position within the network.

It is important to recognise that often social network data are incomplete, meaning some nodes and/or ties may be missing from the dataset (Kossinets, 2003). Incompleteness can arise from several sources including, the so-called 'Boundary Specification Problem' (Laumann *et al.*, 1983); respondent inaccuracy (Bernard *et al.*, 1984); non-response in network surveys (Rumsey, 1993); or introduced inadvertently through study design (Kossinets, 2003). Informant inaccuracy has received a lot of attention in recent decades, and represents any case where respondents reflect the cognitive networks as opposed to the actual interaction pattern, i.e. they report what they think interactions in the network are, rather than what interactions actually happen in reality (Kossinets, 2003).

4.2. Method: Analysis of Survey Data

Using the analysis tool, UCINET (Borgatti *et al.*, 2002), the data collected from the surveys were analysed. The construction of a network requires thought into the choice of entities to be represented in the network, for example, are they individuals or organisations, along with the relationships such as friendship, advice, or co-work etc. To visualise the network, the software package, NetDraw (Borgatti, 2002) part of the larger UCINET package was used (Borgatti *et al.*, 2002). To create the network diagram(s), referred to as sociograms, a binary network matrix was first created, indicating the presence or absence of a tie between stakeholder organisations (Figure 4.1). Matrix components were identified as the names of the stakeholder organisations named by participants in the survey. The matrix created was symmetrical in that all the ties between the nodes were assumed undirected and that the relationships were viewed as equal between both stakeholder organisations involved. The relative strength of the ties (see Granovetter, 1973) between the stakeholder organisations were generated using a standardisation of the data from the survey on how the respondents ranked their relationships' importance in terms of the amount of contact with each of the stakeholders they listed. Using the matrix as an input into the NetDraw, sociograms were produced showing the whole network, along with some ego-network sociograms showing the individual networks of some of the stakeholder organisations (see Section 4.3).

Using UCINET, quantitative network metrics can be derived about the network structure, reflecting on the composition of the nodes, including on the power, centrality, positions and roles of the entities. For the whole network, as well as some ego-networks for the Wear catchment, measures of degree, closeness, eigenvector and betweenness centrality were produced, and are defined as follows (Cambridge Intelligence, 2014):

Degree Centrality – *"[A]ssigns an importance score based purely on the number of links held by each node…[counting] how many direct, 'one hop' connections each node has to other nodes within the network…[useful] for finding very connected [nodes], [nodes] who are likely to hold most information or [nodes] who can quickly connect with the wider network."*

Closeness Centrality – *"[S]cores each node based on their 'closeness' to all other nodes within the network…[by calculating] the shortest paths between all nodes, then assigns each node a score based on its sum of shortest paths…[useful] for finding the [nodes] who are best placed to influence the entire network most quickly…Nodes with a high closeness value have*

a lower distance to all other nodes and would therefore be efficient broadcasters of information."

Eigenvector Centrality – *"Like degree centrality, it measures a node's influence based on the number of links it has to other nodes within the network. [Eigenvector centrality] then goes a step further by also taking into account how well connected a node is, and how many links their connections have, and so on through the network. By calculating the extended connections of a node, [eigenvector centrality] can identify nodes with influence over the whole network, not just those directly connected to it."*

Betweenness Centrality – *"Measures the number of times a node lies on the shortest path between other nodes. [Betweenness centrality] shows which nodes act as 'bridges' between nodes in a network. It does this by identifying all the shortest paths and then counting how many times each node falls on one [, and is] useful for finding the individuals who influence the flow around a system."*

	NW	WRT	DHC	DU	DCC	NEENP	EA	STC	Exhibit "A"rt	NPAONB	DWT	SCC
NW	1	1	1	1	1	1	1	1	0	0	0	0
WRT	1	1	1	1	1	0	1	1	1	1	0	1
DHC	1	1	1	0	1	0	0	0	0	0	0	0
DU	1	1	1	1	0	0	1	0	0	0	0	0
DCC	1	1	1	0	1	0	1	1	0	1	0	1
NEENP	0	0	0	0	0	1	1	0	0	0	0	0
EA	1	1	1	1	1	1	1	1	0	1	0	1
STC	0	0	0	0	0	0	0	1	0	0	0	0
Exhibit "A"rt	0	0	0	0	0	0	0	0	1	0	0	0
NPAONB	1	1	1	0	0	0	1	0	0	1	0	0
DWT	1	1	0	0	0	1	1	0	0	0	1	1
SCC	1	1	1	0	0	0	1	0	0	0	0	1
GNE	1	1	0	0	0	0	1	1	0	0	0	0
CA	1	1	0	0	0	0	1	0	0	0	0	0
Greggs Plc.	0	1	0	0	0	0	0	0	0	0	0	0
The RT	0	1	0	0	0	0	0	0	0	0	0	0
FBA	0	1	0	0	0	0	0	0	0	0	0	0
NE	1	1	1	0	1	1	1	0	0	1	0	1
NT	1	0	0	0	1	0	0	0	0	0	0	0
MMO	1	0	0	0	0	0	0	0	0	0	0	0
WT	0	1	0	0	1	0	0	0	0	0	0	0
Local Landowners	0	1	0	0	1	0	0	0	0	0	0	1
Defra	0	1	0	0	0	0	1	0	0	0	0	0
TeRT	0	0	0	0	1	0	0	0	0	0	0	0
TyRT	0	0	0	0	1	0	0	0	0	0	0	1
Riverfly P/ship	0	1	0	0	0	0	0	0	0	0	0	0
Community Groups	0	0	0	0	0	0	0	0	0	0	0	1
RPA	0	0	0	0	0	1	0	0	0	0	0	0

Figure 4.1: Part of the binary network matrix for stakeholder organisations in the Wear Catchment (1 = indicates presence of a tie between stakeholder organisations; 0 = indicates absence of a tie between stakeholder organisations).

4.3. Results: Analysis of Survey Data

In total 31 people completed the survey from 11 organisations. Figure 4.2 shows a representation of the catchment social network as a combination of nodes (stakeholder organisations) and links as the resulting sociogram for the whole-network of stakeholders working in water-resource management in the Wear Catchment derived using the survey

data. In the network there are a total of 32 nodes, and 92 ties. (For reference the names of the organisations are given in Table 4.1 to which the acronyms in the sociograms refer.) Stakeholders include those from the public, private and voluntary and charity sectors as shown by the colours of the nodes. The links between the nodes depict the presence of a connection between the stakeholders. The components of the network represent a snapshot in time (Spring-Summer 2018), which may or may not change over time due to both the temporary nature of some relationships in the network, which may only be in current existence at the project-scale or as single one-off interactions. A snapshot, however, is valuable in the case of this research in being able to investigate the current state of the network of stakeholders involved in water-resource management in the Wear Catchment in relation to collaborative working, and of the CaBA.

The network has a density score of 9.3%, which is the proportion of all possible ties in the network that are actually present. The most connected stakeholders, i.e. those with the most connections are at the centre of the network. Moving outwards, the number of ties associated with each of the stakeholders decreases. However, it is important to note that the stakeholders located on the peripheries of the diagram are not necessarily those who are unimportant or peripheral stakeholders, and instead represent the boundaries of the network in the Wear Catchment in the context of this research. Stakeholders at the centre of the sociogram are the Wear Rivers Trust, North Pennines AONB, Durham County Council, Sunderland City Council, Natural England, Durham Heritage Coast, Northumbrian Water, and the Environment Agency.

Moving beyond the centre of the network (Figure 4.2), organisations include Durham Wildlife Trust, the Coal Authority, South Shields Council, Groundwork North East and Cumbria, Durham University, and Stanley Town Council. On the peripheries of the network, stakeholder organisations include, neighbouring Rivers Trusts, local landowners, and businesses including Greggs Plc., Killhope Mining Museum, and Lambton Estates (Figure 4.2). Table 4.2 provides brief descriptions of the organisations on the peripheries of the water-resource management network of the Wear Catchment.

Table 4.1: Names of stakeholder organisations referred to in the sociograms (stakeholder organisations highlighted in bold are where survey respondents are from).

Public Sector	Private Sector	Charity or Voluntary Sector
Community Groups	Local Landowners	Tees Rivers Trust (TeRT)
Sunderland City Council (SCC)	Lambton Estates	Tyne Rivers Trust (TyRT)
Marine Management Organisation (MMO)	Greggs Plc.	National Trust (NT)
Rural Payments Agency (RPA)	Killhope Mining Museum	Durham Wildlife Trust (DWT)
Natural England (NE)	**Northumbrian Water (NW)**	Groundwork North East and Cumbria (GNE)
South Shields Council (SSC)	**North East England Nature Partnership (NEENP)**	**Wear Rivers Trust (WRT)**
Durham County Council (DCC)		**Exhibit "A"rt**
North Pennines Area of Outstanding Natural Beauty (NPAONB)		The Rivers Trust (The RT)
Durham Heritage Coast (DHC)		Riverfly Partnership (Riverfly P/ship)
Environment Agency (EA)		Woodland Trust (WT)
Stanley Town Council (STC)		
Durham University (DU)		
Coal Authority (CA)		
Defra		
Forestry Commission (FC)		
Freshwater Biological Association (FBA)		

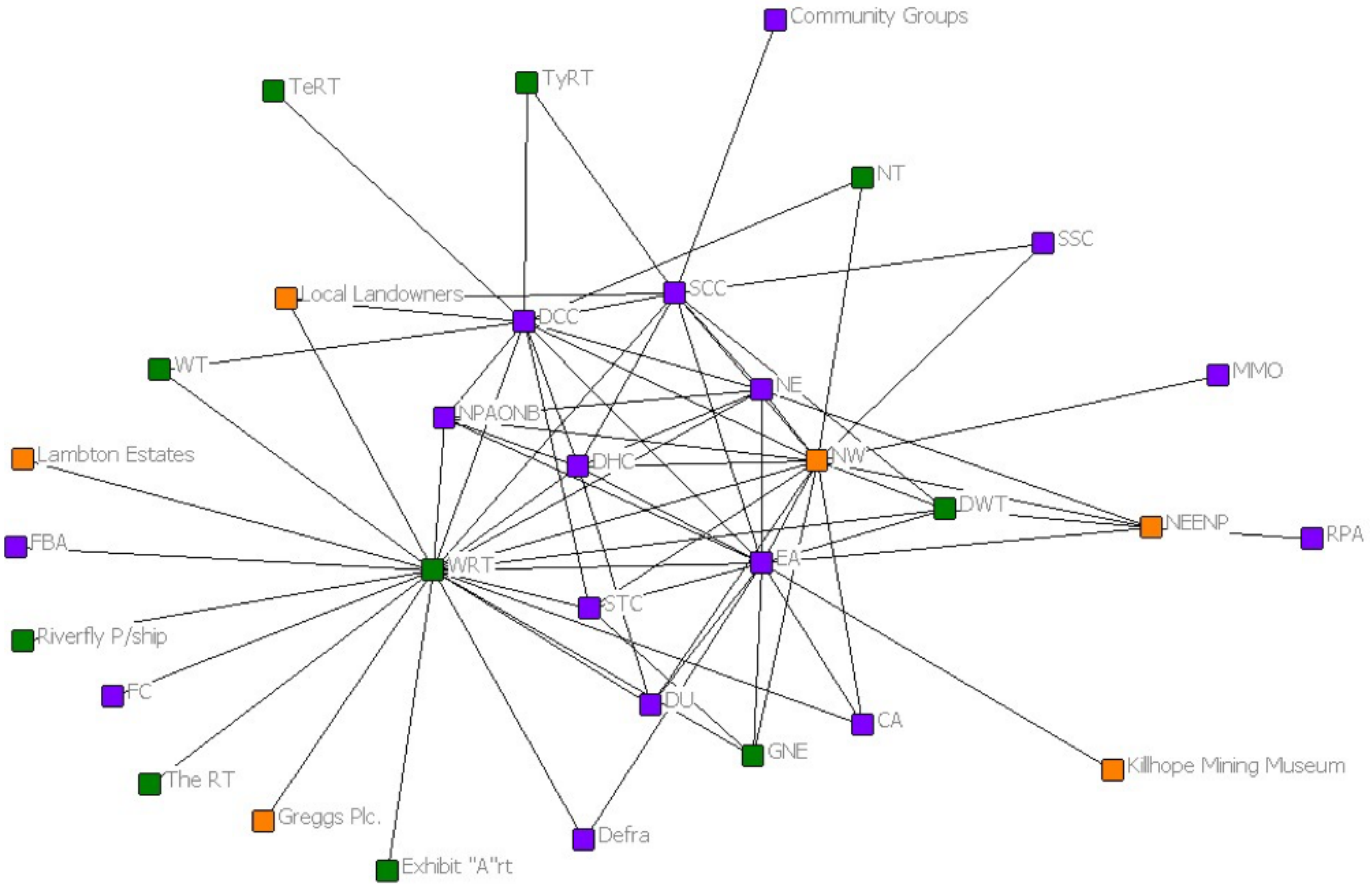

Figure 4.2: Whole-network sociogram depicting the network of stakeholder organisations working in water-resource management in the Wear Catchment created using survey responses (Purple nodes are public organisations; orange nodes are private organisations; and green nodes are environmental NGOs.

In the network, the Wear Rivers Trust has the greatest number of ties to other stakeholder organisations (Figure 4.3). Of the 21 stakeholder organisations the Wear Rivers Trust is connected to, six are voluntary or charity sector organisations (Figure 4.3). Private sector stakeholders connected to the Wear Rivers Trust are local landowners, Lambton Estates, Greggs Plc., and Northumbrian Water. The majority of the connections the Wear Rivers Trust have are with public sector organisations, which are Natural England, Sunderland City Council, Durham County Council, North Pennines Area of Outstanding Natural Beauty (AONB), Durham Heritage Coast, Stanley Town Council, Durham University, the Coal Authority, Defra, the Forestry Commission, and the Freshwater Biological Association (Figure 4.3).

Table 4.2: Descriptions of the organisations on the peripheries of the water-resource management network of the Wear Catchment.

Organisation	Description of the organisation
Tyne Rivers Trust	Charitable organisation that is guardian of the River Tyne Catchment, responsible for overseeing the continued conservation and regeneration of the river (Tyne Rivers Trust, 2019).
Tees Rivers Trust	Charitable organisation committed to improving and conserving the River Tees, with key areas of work including research, education and habitat improvements, working closely with community groups (Tees Rivers Trust, 2017).
Local Landowners	Landowners in the River Wear Catchment.
Greggs Plc.	North-east founded bakery business, with over 1,700 shops across the UK (Greggs, 2018). In the context of water-resource management in the Wear Catchment, Greggs have provided refreshments to volunteers while working on river restoration and management tasks with the Wear Rivers Trust.
Killhope Mining Museum	Multi-award winning 19th Century mining museum located in the North Pennines AONB, offering visitors the chance to experience life and work involved in lead mining in the North Pennines (Killhope Lead Mining Museum, 2019).
Lambton Estates	The seat of the Earls of Durham, and home to Biddick Hall and Lambton Castle. The Estate comprises 1,200 acres of sporting, woodland, and farming enterprises; and is also home to Bowes Business Park offering modern office facilities. More than 60 houses are also situated on Lambton Estates (Lambton Estates Ltd., 2019).

Figure 4.4 shows the strength of ties between the stakeholder organisations, making use of the scores survey respondents assigned to each of the organisations listed in terms of the amount of contact they have with them. For each of the responses received, rankings allocated to the stakeholder organisations they listed were collated and averaged. The highest and lowest ranking contacts are shown in Table 4.3. The Environment Agency and the Wear Rivers Trust were listed as the highest-ranking contact for three and two of the 11 stakeholder organisations respectively. The Environment Agency was ranked highest by Northumbrian Water, Durham Heritage Coast and Sunderland City Council; and the Wear Rivers Trust was ranked highest by Stanley Town Council and Durham University. The Wear Rivers Trust ranked Natural England and the Forestry Commission highest, even though neither of the organisations are central to the water-management network in the Wear Catchment. Durham County Council ranked Durham Heritage Coast the highest, whereas Durham Heritage Coast ranked the Environment Agency the highest. As the Wear Rivers Trust was the only stakeholder mentioned by Exhibit "A"rt, the Trust was ranked both as the highest and lowest contact. Focusing on the lowest rankings listed in Table 4.3, Durham Heritage Coast ranked Northumbrian Water and the Wear Rivers Trust as their lowest contact, but Northumbrian Water and the Wear Rivers Trust ranked their lowest contacts as South Shields Council and Greggs Plc., respectively. The Environment Agency and Durham University both ranked one another as their lowest contact.

Table 4.3: Lowest and highest-ranking contacts for each of the stakeholder organisations who completed the survey.

Stakeholder Organisation	Lowest Ranking Contact	Highest Ranking Contact
Northumbrian Water	South Shields Council	Environment Agency
North East England Nature Partnership	Durham Wildlife Trust	Rural Payments Agency
Durham Heritage Coast	Northumbrian Water; Wear Rivers Trust	Environment Agency
Durham University	Environment Agency	Wear Rivers Trust
Durham County Council	Tyne Rivers Trust	Durham Heritage Coast
Environment Agency	Durham University	Northumbrian Water
North Pennines AONB	Environment Agency	Natural England
Sunderland County Council	Natural England	Environment Agency
Stanley Town Council	Groundwork North East	Wear Rivers Trust
Wear Rivers Trust	Greggs Plc.	Natural England; Forestry Commission
Exhibit "A"rt	Wear Rivers Trust	

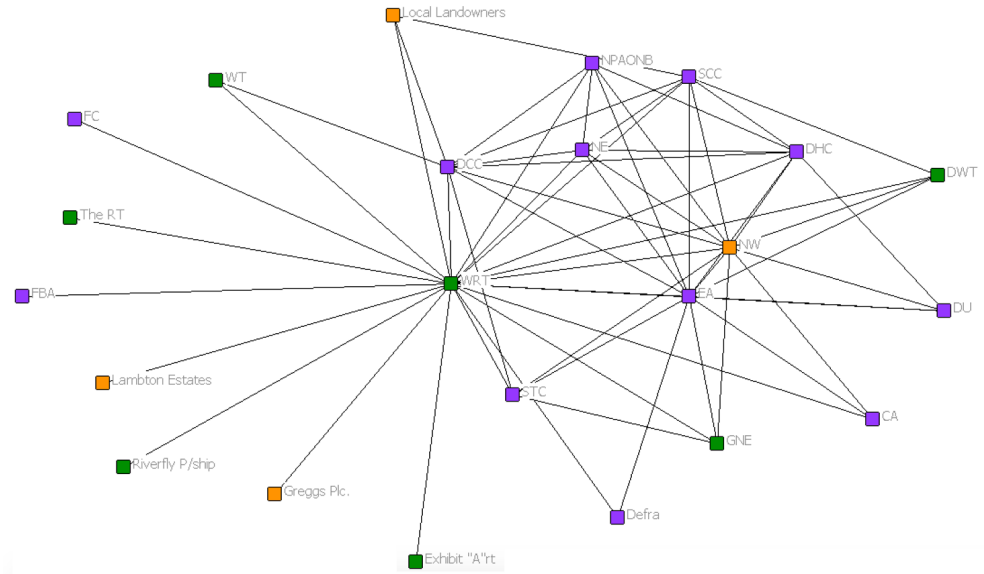

Figure 4.3: Ego-network for the Wear Rivers Trust.

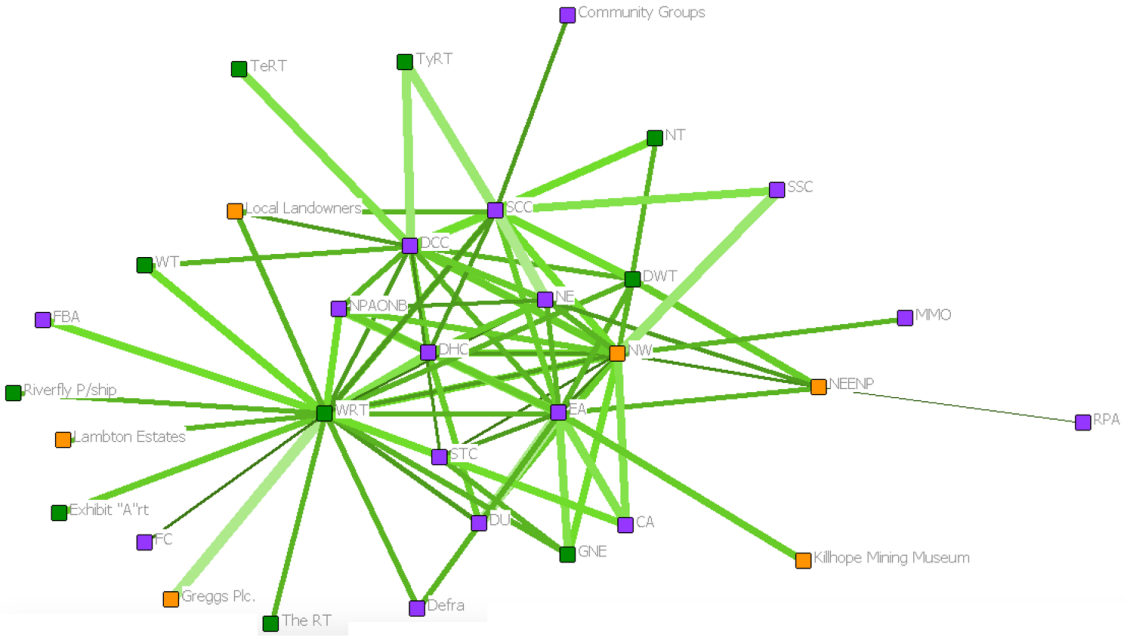

Figure 4.4: Whole-network sociogram showing strength of ties between stakeholder organisations working in water-resource management in the Wear Catchment created using survey responses (the darker the shading and the thicker the line, the stronger the tie).

The purpose of the links between the stakeholder organisations are shown in Figures 4.5 to 4.8, showing interactions for problem-solving, political support, decision-making, and the acquisition of data and information respectively, which were reported by survey respondents (see Table 4.1). Of the stakeholder organisations shown in Figure 4.5, the

Wear Rivers Trust has the largest number of organisations whom they rely on for problem-solving interactions. There are 10 stakeholders the Wear Rivers Trust problem-solve with, but only four of the relationships are reciprocated, those with Durham County Council, Sunderland County Council, Durham University, and Durham Heritage Coast. The Wear Rivers Trust also rely on Northumbrian Water, the Coal Authority, Groundwork North East, the Rivers Trust, North Pennines AONB, and the Environment Agency for problem-solving support. Northumbrian Water has two-way problem-solving interactions with Durham Heritage Coast, Durham University and the Environment Agency, and also rely on Natural England and Sunderland City Council for assistance with problem-solving. Similar to the Wear Rivers Trust and Northumbrian Water, Durham County Council also has reciprocated problem-solving interactions with Durham Heritage Coast. The Environment Agency also has contact with Natural England, the Coal Authority, North East England Nature Partnership, Durham Wildlife Trust and Sunderland City Council.

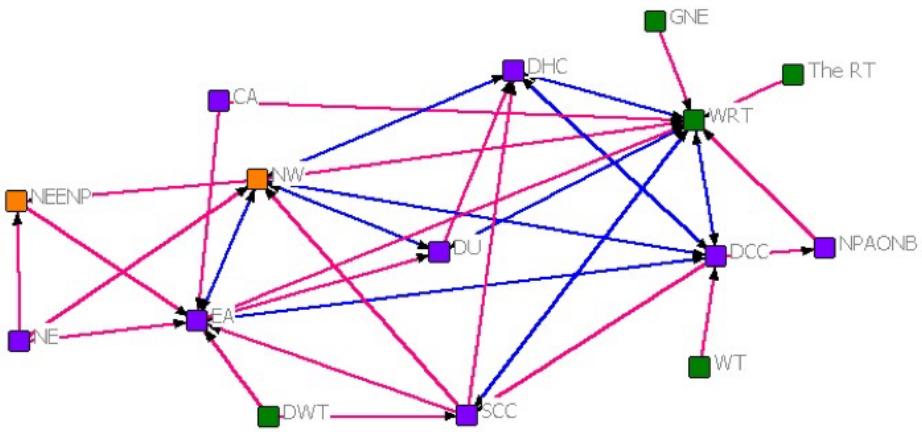

Figure 4.5: Sociogram showing problem-solving interactions between stakeholder organisations, pink lines are one-way problem-solving, and blue lines are two-way problem-solving interactions.

Of the stakeholder organisations who provide and/or receive political support, the three stakeholders with the highest number of links are the Wear Rivers Trust, Northumbrian Water, and the Environment Agency (Figure 4.6). Northumbrian Water has 11 political support links in total, five of which are reciprocated between Northumbrian Water and other stakeholder organisations, which are with Durham University, Durham Heritage Coast, the Wear Rivers Trust, Durham County Council and the Environment Agency. The Environment Agency and the Wear Rivers Trust both have reciprocated contact regarding

political support with Durham University and North Pennines AONB. As shown in Figure 4.6, however, much political support is one-way. On the peripheries of the political support sociogram, the following organisations provide, but do not receive political support from stakeholders, and are, Durham Wildlife Trust, the Coal Authority, Groundwork North East and Cumbria, Sunderland City Council, the Rivers Trust, Lambton Estates, and the Woodland Trust. None of the stakeholders listed community groups, the Marine Management Organisation, South Shields Council, local landowners, Greggs Plc., the Tees Rivers Trust, the Tyne Rivers Trust, the National Trust, Exhibit "A"rt or the Riverfly Partnership as stakeholders who they have contact with regarding political support.

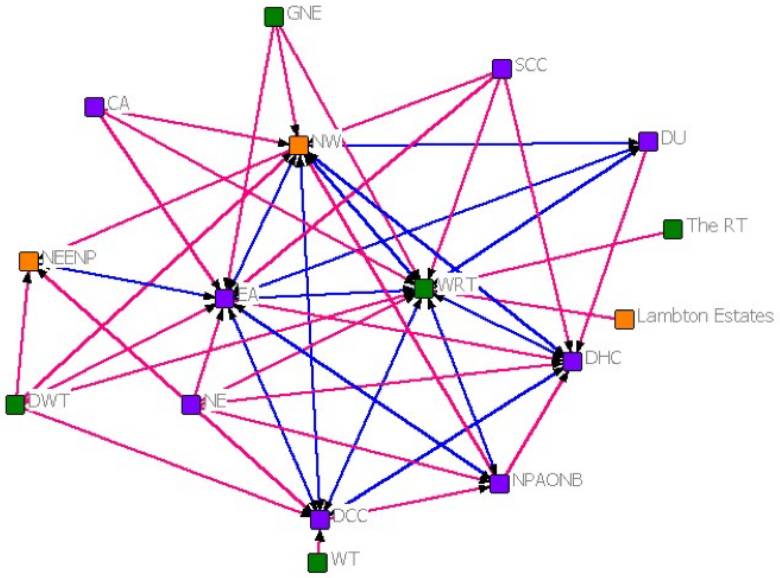

Figure 4.6: Sociogram showing political support interactions between stakeholder organisations, pink lines are one-way political support, and blue lines are two-way political support interactions.

Figure 4.7 shows the decision-making interactions between stakeholder organisations. Of the organisations shown, the Wear Rivers Trust and the Environment Agency have the highest number of decision-making interactions with other stakeholders. Incoming decision-making interactions to the Wear Rivers Trust are from Groundwork North East, the Rivers Trust, Lambton Estates, the Woodland Trust, Durham Wildlife Trust, Sunderland City Council, and the Environment Agency. Durham University, Northumbrian Water, Durham County Council, Durham Heritage Coast, and North Pennines AONB have two-way decision-making interactions with the Wear Rivers Trust (Figure 4.7). The

Environment Agency have 10 decision-making interactions with stakeholder organisations shown in Figure 4.7, four of which are reciprocated, with Sunderland City Council, Durham County Council, North Pennines AONB, and Northumbrian Water.

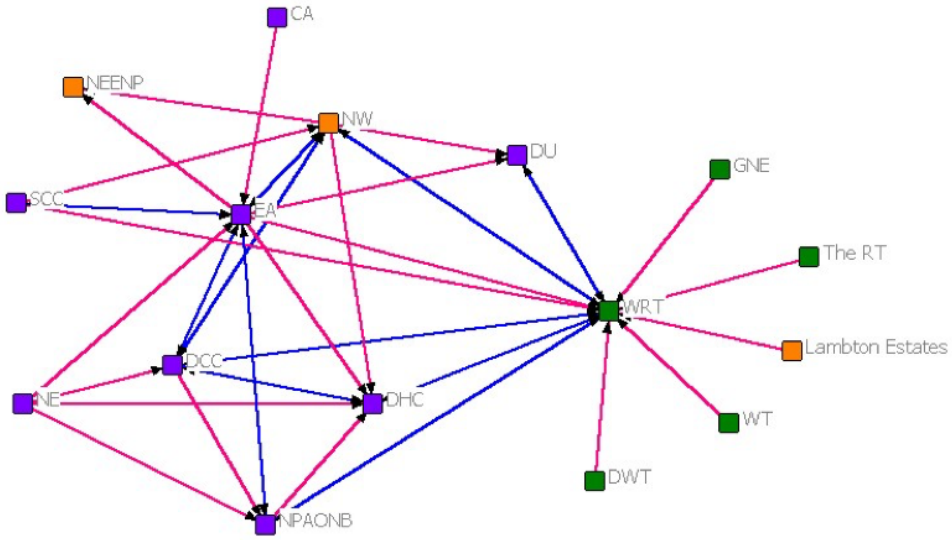

Figure 4.7: Sociogram showing decision-making interactions between stakeholder organisations, pink lines are one-way decision-making, and blue lines are two-way decision-making interactions.

Stakeholder organisations who provide data and/or information to other organisations are shown in Figure 4.8. Compared to Figures 4.5 to 4.7, Figure 4.8 shows the highest interaction between stakeholders in terms of the number of ties present. The Wear Rivers Trust has the highest number of data and information sharing interactions, nine of which are one-way interactions with organisations providing the data and/or information to the Wear Rivers Trust, and seven which are reciprocated with a two-way sharing of data and/or information. Northumbrian Water have 11 interactions, seven of which are one-way from Northumbrian Water. Durham County Council, the Wear Rivers Trust, Durham University, and the Environment Agency have a two-way data and/or information sharing process with Northumbrian Water. Dissimilar to the other forms of interaction considered, for data and/or information sharing contact exists between stakeholder organisations and the Freshwater Biological Association, the Forestry Commission and Defra.

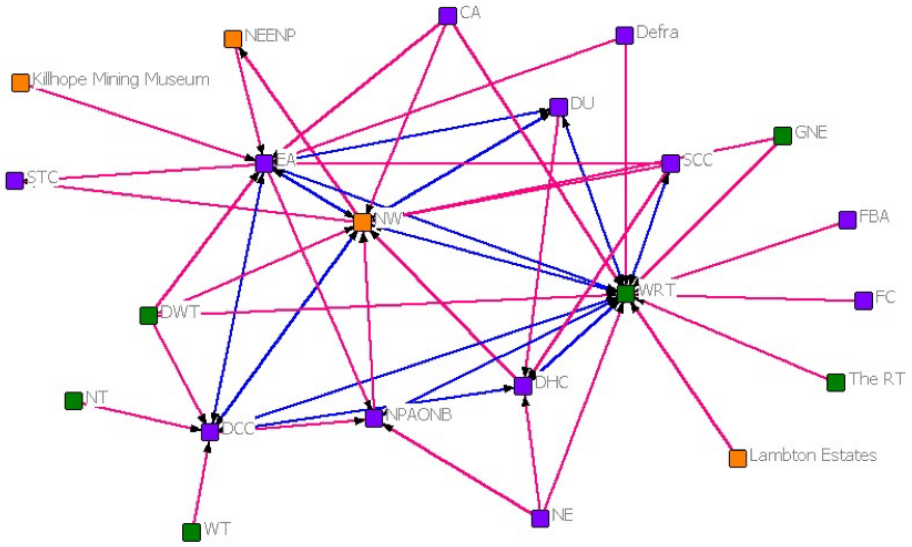

Figure 4.8: Sociogram showing the sharing and/or acquisition of data and information interactions between stakeholder organisations, pink lines are one-way transfer of data and/or information, and blue lines are two-way movement of data and/or information.

Using UCINET, various measures were also produced, focusing on the network as a whole. Network metrics about the structure of the network are presented in Figures 4.9 to 4.12, showing, degree, closeness, eigenvector and betweenness centrality respectively. In each of the figures, node sizes are representative of the network metric being displayed with node size being proportionally sized to the metric score, i.e. the higher the score, the larger the node.

The organisation with the highest degree, closeness, eigenvector centrality and betweenness scores is the Wear Rivers Trust, with scores of 71%, 75.6%, 39.6% and 49.6% respectively (Figures 4.9 to 4.12). Northumbrian Water has the second highest scores, which for degree and betweenness are 19.4% and 30.9% lower respectively than the scores for the Wear Rivers Trust (Figures 4.9 and 4.12). The Environment Agency has the third highest scores for betweenness, closeness, and eigenvector centrality, which are 48.4%, 66.0% and 36.2% respectively (Figures 4.10, 4.11 and 4.12). Durham County Council and the Environment Agency have the third and fourth highest scores of 14.3 and 14.4% respectively for betweenness (Figure 4.12).

For degree, closeness and eigenvector centrality, Sunderland City Council, Durham Heritage Coast and Natural England have the fifth, sixth and seventh highest scores (Figures 4.9, 4.10 and 4.11). For degree (Figure 4.9), the rest of the organisations have

scores of less than 20%. The three organisations with the lowest eigenvector centrality scores (Figure 4.11) are the Tees Rivers Trust, community groups, and the Rural Payments Agency. Durham Wildlife Trust, Durham Heritage Coast and Stanley Town Council have three of the lowest betweenness scores of 1.3, 0.4 and 0.1% respectively (Figure 4.12). Closeness scores for North Pennines AONB, Durham Wildlife Trust and Stanley Town Council are 59.6%, 53.4% and 52.5% respectively (Figure 4.10). The rest of the organisations have closeness scores of 50% or less, the lowest of which is for the Rural Payments Agency with a score of 31.3% (Figure 4.10).

Figure 4.13 shows the blocks and cut points in the network. The blocks into which cut points divide the network are given in Table 4.4. Stakeholder organisations which act as cut-points in the network, i.e. an organisation, removal of which would break up a network into disconnected parts, are, Northumbrian Water, the Wear Rivers Trust, Durham County Council, North East England Nature Partnership, the Environment Agency, and Sunderland City Council. As detailed above, these stakeholder organisations are key contacts in terms of problem-solving, decision-making, political support and in the sharing of data and/or information with regards to the management of water resources in the Wear Catchment, in particular the Wear Rivers Trust who has the highest number of reciprocated ties with other stakeholder organisations. Without these stakeholders there would be an impact on for example the flow of information, decision-making processes, which would be potentially detrimental to the management of water resources in the Wear Catchment.

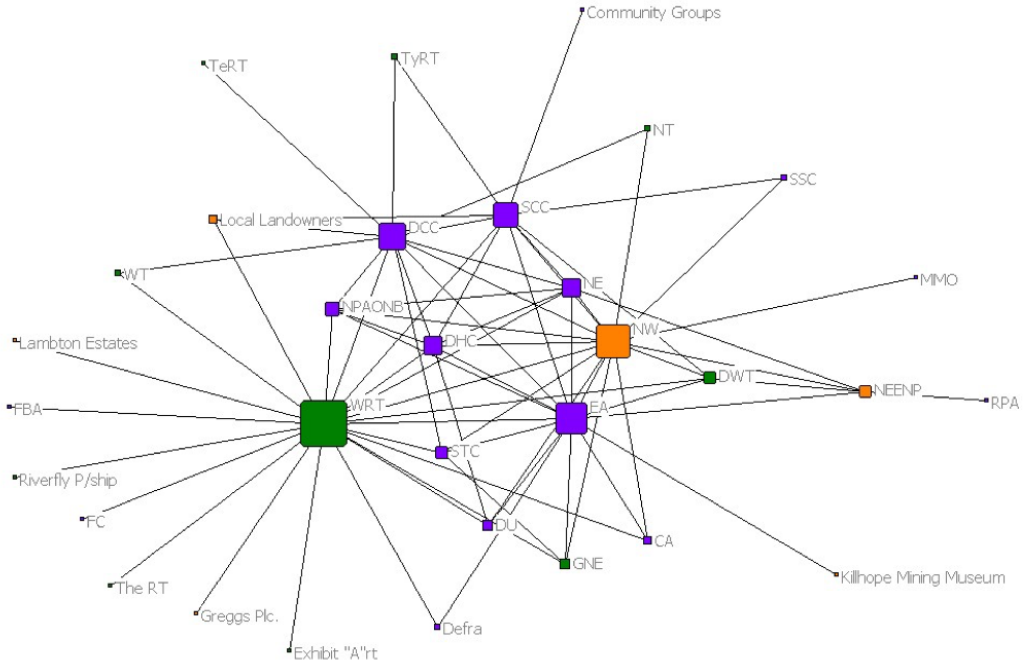

Figure 4.9: Sociogram showing the degree score, represented by node size (the higher the score, the larger the node), for each of the stakeholder organisations in the network.

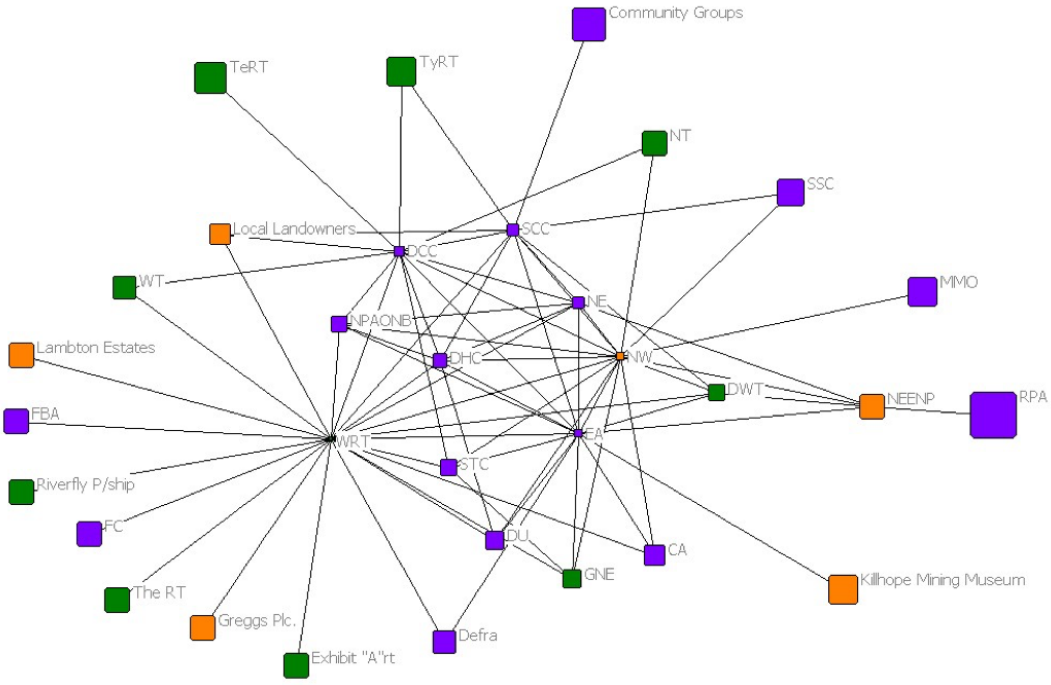

Figure 4.10: Sociogram showing the closeness score, represented by node size (the higher the score, the larger the node), for each of the stakeholder organisations in the network.

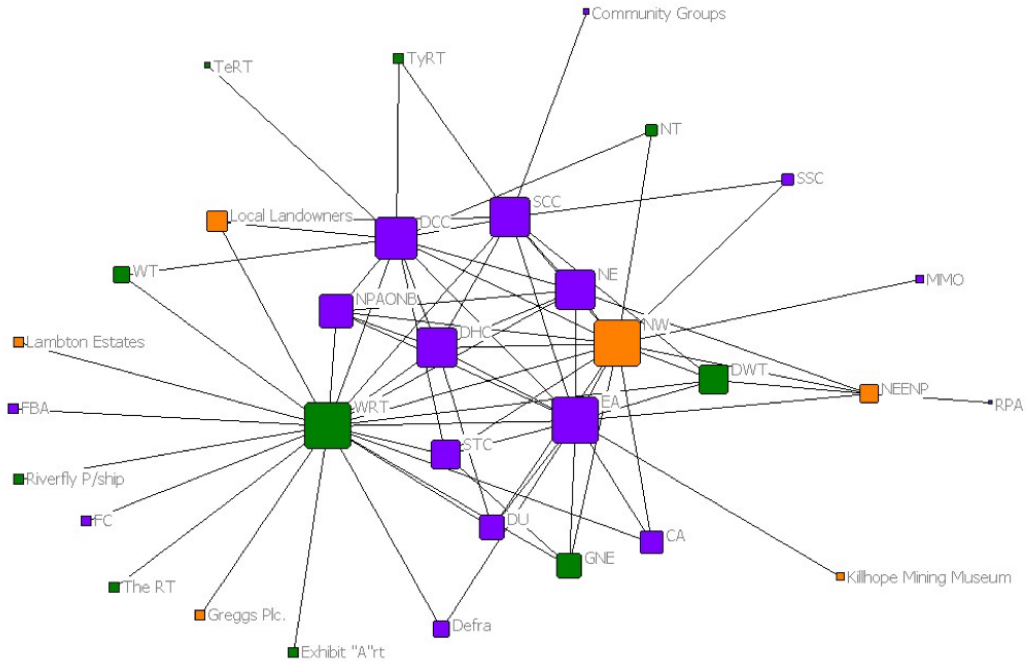

Figure 4.11: Sociogram showing the eigenvector centrality score, represented by node size (the higher the score, the larger the node), for each of the stakeholder organisations in the network.

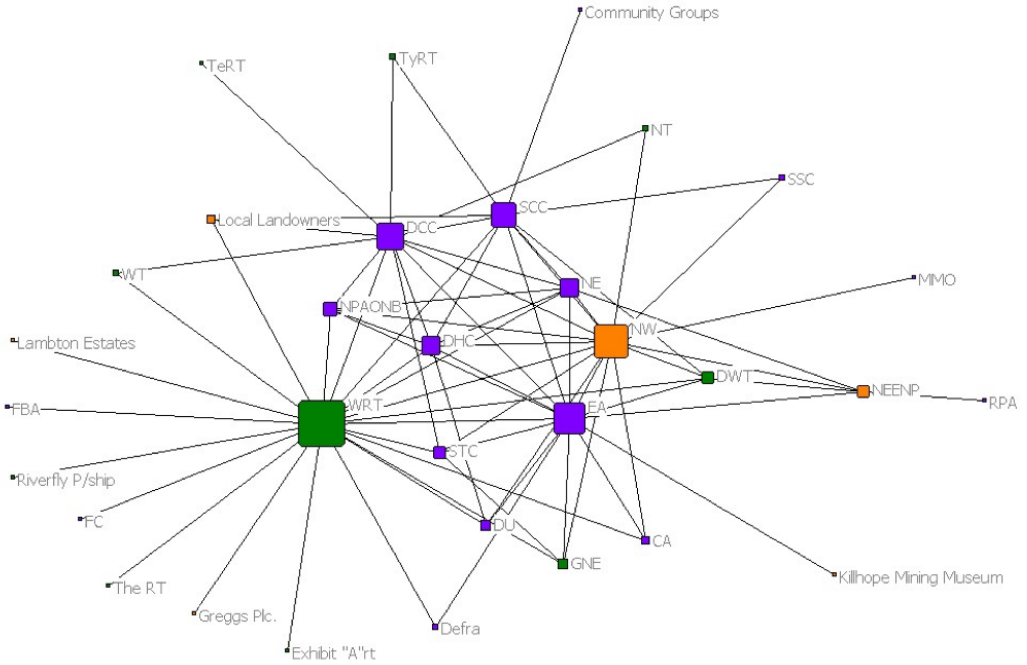

Figure 4.12: Sociogram showing the betweenness score, represented by node size (the higher the score, the larger the node), for each of the stakeholder organisations in the network.

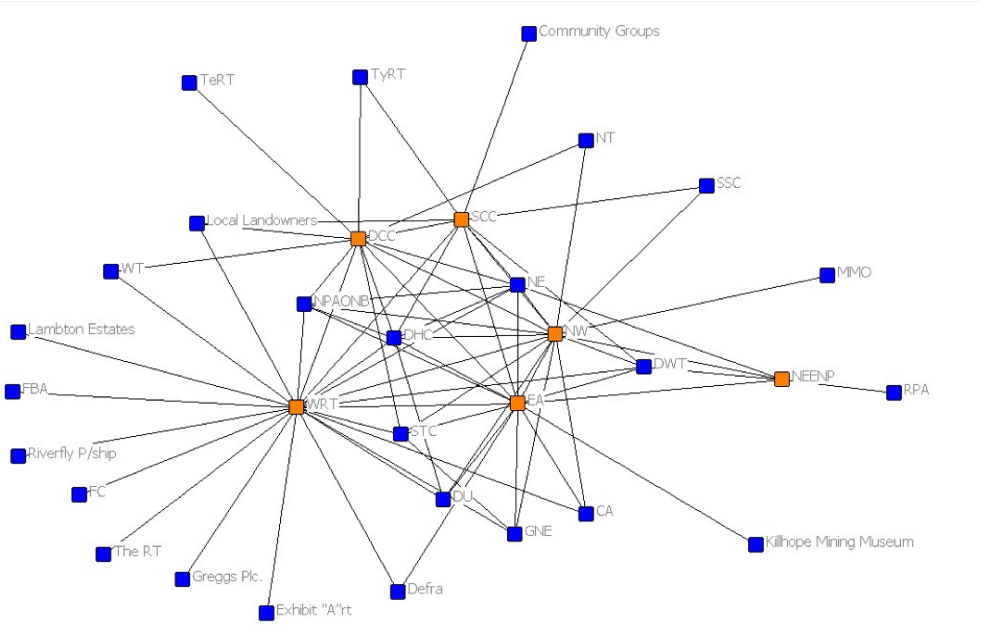

Figure 4.13: Blocks and cut-points in the network – blocks are shown by the blue nodes and cut-points are shown by the orange nodes.

Table 4.4: Blocks into which cut-points divide the network.

Block Number	Stakeholder Organisations
1	Sunderland City Council; Community Groups
2	North East England Nature Partnership; Rural Payments Agency
3	Durham County Council; Tees Rivers Trust
4	Environment Agency; Killhope Mining Museum
5	Wear Rivers Trust; Exhibit "A"rt
6	Wear Rivers Trust; Greggs Plc.
7	Wear Rivers Trust; The Rivers Trust
8	Wear Rivers Trust; Freshwater Biological Association
9	Wear Rivers Trust; Riverfly Partnership
10	Wear Rivers Trust; Lambton Estates
11	Wear Rivers Trust; Forestry Commission
12	Northumbrian Water; Wear Rivers Trust; Durham Heritage Coast; Durham University; Durham County Council; North East England Nature Partnership; Environment Agency; Stanley Town Council; North Pennines AONB; Durham Wildlife Trust; Sunderland City Council; Groundwork North East and Cumbria; Coal Authority; Natural England; National Trust; Woodland Trust; Local Landowners; Defra; Tyne Rivers Trust; South Shields Council
13	Northumbrian Water; Marine Management Organisation

4.4. Discussion

Through the depiction of the stakeholder organisations in the Wear as a network, it has allowed for a conceptualisation of the relationships between the stakeholders involved and their relative positions within the network in terms of working together to manage water issues in the catchment to be investigated. Therefore, offering one possible understanding of the construction of the system of stakeholders working in the catchment, and also a means of being able to base an assessment and investigation of the current state of collaborative water-resource management with respect to the CaBA. Links in the network represent social relations such as knowledge exchanges, and flows of information or resources between nodes, in this case, stakeholder organisations in the Wear Catchment network (Scott, 2015).

Focusing on the structure of the network, (see Figure 4.2), the stakeholders at the centre of the network are all public sector organisations, with the exception of the Wear Rivers Trust and Northumbrian Water, which are a charity sector and a private-sector organisation respectively. Centrality can be defined individually for each node in the network, as well as across the total network. Individually, centrality is the number of links a node has (Freeman, 1978), which in the case of this research is the number of stakeholder organisations each of the stakeholders in the network is linked with. A highly centralised network is where a minority of nodes hold the majority of ties (Prell *et al.*, 2009); and is true for the network of the Wear Catchment.

Newig *et al.* (2010) make the claim that the centrality of an actor (stakeholder) relates to their power or influence in the network. In the network of catchment-management in the Wear it is the Wear Rivers Trust and Northumbrian Water who have the highest and second highest number of connections in the network respectively, closely followed by the Environment Agency. The Wear Rivers Trust and the Environment Agency are connected to a mix of public, private and charity and voluntary sector organisations, whereas, the majority of connections Northumbrian Water has are with public sector organisations.

With the highest score of 71% for degree centrality, the Wear Rivers Trust is a very well-connected stakeholder and is the stakeholder organisation in the network who is likely to hold the most information or individuals who can quickly connect with the wider network as a whole. A closeness score of 75.6% supports that the Wear Rivers Trust is a good

'broadcaster' (see closeness centrality definition in section 4.2), with relatively short paths to a high number of stakeholders, putting the Trust in the best position of all stakeholders in the network to influence the entire network most quickly, and shows the Trust is carrying out its role effectively as the host of the Wear Catchment Partnership. The well-connected central position of the Wear Rivers Trust is likely to be attributable to their purpose as a charity focused on the water environment of the Wear Catchment, and their mission as an organisation as an environmental charity, "to conserve, protect, rehabilitate and improve the landscape and watercourses of the whole River Wear Catchment" (Wear Rivers Trust, 2017).

In order for them to work on their mission, the Wear Rivers Trust need to work with a number of stakeholders operating in the catchment be they landowners, regulators and planning authorities, and asset owners, including the councils and Northumbrian Water, for example. As the host of the Wear Catchment Partnership, the Wear Rivers Trust are responsible for the planning and organisation of partnership meetings and are thus central to the catchment as a whole in working towards the goals of the WFD and collaborative working in line with the CaBA. As an environmental charity, the Wear Rivers Trust relies on grants and (joint-)project funding and ideas from other organisations in the catchment. Despite being very knowledgeable of the local landscape, the Trust is reliant on the input and assistance of other organisations, which is supported by the many links with other organisations for problem-solving, political support, decision-making and in the sharing of data and/or information (Figures 4.5 to 4.8).

Similar to the Wear Rivers Trust, the central and highly connected position of Northumbrian Water is likely to be attributable to its purpose as an organisation as a regulated water and sewage company, responsible for water and wastewater management in the North-east of England. Therefore, links with the local councils as planning authorities and landowners where Northumbrian Water assets are located are essential.

The Environment Agency also holds a high number of links (see Figure 4.2). The centrality of the Environment Agency is likely to be attributable to the regulatory function of the organisation, as well as its wide-ranging association with organisations and groups in the management of and interaction with the natural environment in the Wear Catchment. It is likely that the Environment Agency is an influential and highly-connected actor in the catchment network due to the wide range of interactions, ranging from regulation, to

policy information and advice, to funding, to co-leading partnerships, such as the Wear Catchment Partnership, to monitoring and delivering projects, assigning pollution status of waterbodies, and responding to emergencies. In doing-so they are interacting with a wide-range of stakeholders for a number of reasons, which is enabled by the vast size of the organisation, and the number of staff who can maintain relationships and varying capacities of interaction across the catchment with other stakeholder organisations.

Ultimately, if the Wear Rivers Trust, Northumbrian Water and the Environment Agency were to be removed from the network, it would result in a break-up of the network into disconnected parts. This could have detrimental effects on the functioning of the catchment-management system, reducing collaborative working potential, lowering the ability of managing water resources across the Wear Catchment, affecting for example the achievement of the goals of the WFD.

The strength of ties between stakeholders is also an important consideration to take into account in the analysis of networks (Granovetter, 1973). In the social network literature, links are referred to as either being strong or weak, both of which can be advantageous and restrictive. The balance of links, strong and weak, is said to be indicative of the network nature. Strong links are indicative of the ability of stakeholders to influence one another, as well as, share views, offer support, communicate effectively, and to develop and maintain a trusting working relationship (Prell *et al.*, 2009). Strong links can, however, be problematic in that they typically exist between stakeholders who are similar, be that in style of working or in temperament, resulting in the tendency to get locked into ways of thinking, something which may lead to cognitive blocking (Messner, 1995) and group thinking (Janis, 1982). Strong links exist between the Environment Agency and a number of stakeholder organisations, including, Northumbrian Water, Durham Heritage Coast and, Sunderland City Council, for example. These organisations are key to holding the network of stakeholders in the Wear Catchment together, and are important in decision-making, in the acquisition and sharing of data and/or information, problem-solving, and offering political support to one another, as well as to other stakeholders in the catchment. The removal of any of these stakeholders could have detrimental effects on the functioning of water-resource management in the catchment.

Weak ties on the other hand are seen to be associated with less frequent communication between the stakeholders. Weak ties, however, can be advantageous as unlike strong links, weak links are often between more diverse stakeholders, meaning more diverse

information can be exchanged between them (Prell *et al.*, 2009; Newig *et al.*, 2010). Nevertheless, too many weak ties can mean that a network becomes vulnerable, as weak ties are often easily broken or there is a lack of trust between the stakeholders. Ultimately, for stronger relations to form, knowledge of other stakeholders, for example on their working behaviour, and building up a pattern over a length of time is necessary. For example, the Wear Rivers Trust expressed the desire for the formation of a stronger tie with Sunderland City Council, and remain hopeful of this in the future, working more closely with the council as they do at present with Durham County Council (see Chapter 5).

However, the existence of a link between stakeholders does not necessarily equate to a positive relationship and is due to the ability of stakeholders to affect and be able to be affected in unexpected ways by the nature or lack of exchange with other stakeholders. The nature of the relationship between stakeholders may be dependent on the level of trust present. Trust can be affected by the expectations and agendas of the stakeholders, whether or not they have the time and the resources, including employee availability; and whether there are any contradictions or disagreements between the parties involved, such as concern about licencing agreements for data sharing, etc. The notion of trust between stakeholders is important to ensure effective working, and ultimately the management of water resources, which is discussed further in Chapter 5 with reference to responses from stakeholders in their interviews.

Unfortunately, whether there is equity or satisfaction with the exchanges between stakeholders is unknown and is one of the limitations of studying a network structure in isolation, i.e. not all the stakeholder organisations named in the survey had participated in the completion of the survey themselves. With knowledge that some stakeholder organisations did not partake in the completion of the survey, there is some likelihood of missing stakeholders from the network. However, missing data are somewhat unavoidable, as with the majority of data-collection exercises.

The linking together of the social-network data with interviews is essential in this research to build upon and expand concepts such as trust in relation to stakeholder working, and also in delving more into reasons as to why some stakeholders are not connected with others, and why ties exist but are quite weak, etc. Ultimately, SNA revealed a number of questions which can in part be answered by analysis of the network data, but need to be further investigated with interviews (as covered in Chapter 3), including: (1)

what type of data do stakeholders get from or give to each other; (2) which organisations give the most data; (3) which organisations get the most data? As well as, further information on the purposes of the ties between the stakeholder organisations, giving detail beyond whether stakeholders are in contact for data sharing, problem-solving, political support or decision-making; therefore, moving from the what to the why, what they give to each other, to why they give the support they do (or do not give) to each other.

4.5. Assessment of the Current State of the CaBA in the Wear Catchment Based on SNA

Referring back to the CaBA, introduced in Chapter 1 of this thesis, the purpose of this section is to draw on the results of the social network analysis of the catchment-management system, to base an assessment of the current state of the CaBA in the Wear Catchment. To reiterate, the CaBA was first introduced through a series of pilot catchments across the UK, as a novel approach to address water-quality issues at the catchment-scale. The CaBA is intended to localise environmental improvement, involving a wide range of stakeholders in decision-making processes. In the context of the Wear Catchment there is evidence for the involvement of a wide range of stakeholders working together, with stakeholders including the Wear Rivers Trust, Northumbrian Water and the Environment Agency at the centre of management operations. Findings of the purposes of the links between the stakeholders, suggests the existence of several working relationships between the stakeholders, involving the transfer of data and/or information, problem-solving interactions, political support, and support in decision-making.

However, within the Wear Catchment, there is little evidence from the social-network data collected of community involvement. Despite one of the intentions of the CaBA being to provide a means of allowing for community-led approaches, with the intentions of delivering improvements to the water environment. Albeit community groups and local landowners both being listed as stakeholders in the survey responses (see Figure 4.2), there is no evidence of use of their expertise or knowledge with neither group being listed as contacts used for decision-making, political support, problem-solving or data and/or information sharing interactions.

4.6. Summary

Chapter 4 has investigated the social-network of stakeholders currently involved in water-resource management in the Wear Catchment. Background information was given on the methodology involved in SNA, including the use of the survey data collected, and the translation of the data into a network. In-depth analysis was conducted on the network, including who the key central stakeholders in the network are, namely the Wear Rivers Trust, the Environment Agency and Northumbrian Water, along with the identification of stakeholders at the peripheries of the network. The purposes of ties the stakeholders have with others in the network were also investigated. Results showed that the Wear Rivers Trust is a key player in decision-making, problem-solving, political support and in the sharing of data and/or information. Removal of the core stakeholders could have detrimental effects on the structure and functioning of the network, and subsequently on the management of water resources in the catchment. A detailed description of the characteristics of the network is also provided, using network metrics including centrality. The remainder of the chapter comprised the discussion and interpretation of the network, with an assessment of the current state of the CaBA in the Wear Catchment based on the SNA.

Chapter 5 – Thematic Analysis of Interviews

An important part of this research was the bringing together of the social network data collected about the stakeholders involved in water-resource management in the Wear Catchment and qualitative data collected from the interviews, with the intention of being able to develop knowledge and awareness of the relationships between stakeholders identified in the survey responses. Therefore, using the emerging themes from the interview data, the knowledge was used to understand and further interpret and analyse the social network of the stakeholders, assessing the relationships, exchanges and interactions occurring between them, and the collaborative nature of their ways of working in practice in water-resource management in the Wear Catchment with respect to the CaBA.

During interviews, interviewees were able to review their survey responses, and were able to comment on the sociogram(s) produced using their survey responses. By showing the interviewees their sociograms, they were able to move from description to depiction, thereby addressing the potential issue of respondents biasing the data by making iterative engagement with the SNA data a specific part of the analysis. This is in addition to theorising the reasons for the ways they represented features on the sociogram. Combined with semi-structured questioning, the interviews moved from the initial descriptions of what is shown in the sociograms, to elaborating what is meant by the relations shown. By allowing interviewees to interact with the data and information they provided in the survey, it complimented and added to the conventional and more traditional verbal interview style (Emmel, 2008).

In all but two of the interviews audio recordings were taken and were subsequently transcribed to facilitate analysis (Dunn, 2016). The recordings were transcribed in full so as to avoid potential bias in the focus on what had been discussed in the interviews. Transcripts were analysed to seek meaning from the qualitative data, identifying themes, relations between variables and patterns in the data (Dunn, 2016). Content analysis can be based on a search of either manifest or latent content (Babble, 1992 as cited in Dunn, 2016). Manifest content analysis involves assessing the visible, surface content of the transcripts, and involves tallying the appearance of a word or phrase (Dunn, 2016). Latent content analysis involves searching transcripts for themes, and requires an interpretation of what is said (Dunn, 2016). Ultimately, coding can be thought of as a process of

abstraction (Flick, 1998), allowing for comparisons to be drawn between different interviews, identifying key themes and ideas.

To facilitate with the process of coding, the software package NVivo was used. NVivo allows for ease of comparison and cross-referencing between transcripts, and the gathering of codes into themes and sub-themes. Primarily, high-level coding was conducted, with line-by-line reading of each of the transcripts, and the identification of core, cross-cutting themes between the interviews (Strauss, 1987; Flick, 1998). Initially, 12 coding categories emerged from the data, and were: challenges, communication, exchange, distant partners, expertise, importance, relationships (internal and external to the organisations), representation (at the project and partnership levels, and at meetings), responsibility, support, temporal changes, and strength of relationships. Upon re-reading the transcripts and reviewing the coding categories, a further two categories, power and engagement, were added; and at this stage the coding process was deemed to be completed once no new categories for codes seemed to emerge (Esterberg, 2002). The categories identified were grouped into four sections, used in the structuring of this chapter: (1) communication, exchange, responsibility and support; (2) expertise, importance and representation; (3) challenges and temporal changes; and (4) strength of relationships. Throughout the sections reference is made to the relationships and the involvement of the stakeholder organisations in the Wear Catchment Partnership, as well as power and engagement.

5.1. Communication, Exchange, Responsibility & Support

Effective communication between stakeholders is crucial for success (Jackson, 2007). Reiterated by several scholars, including Bendell (2000) and Crane and Livesey (2003) is that an essential building-block in the creation of stakeholder relationships is communication (Foster and Jonker, 2005). Communication affects the ability of organisations to engage, both internally and externally, in order to achieve their objectives (Welch and Jackson, 2007); and to allow and ensure for the exchange of elements within the organisation and with other organisations. Data, information and resources are elements that can be exchanged, and used in processes of co-creation and means of learning between stakeholders. In the Wear Catchment, a number of stakeholders use language referring to the exchange of data, information and resources. Exchange between organisations is largely facilitated by communication, a two-way

process, whereby stakeholders share, discuss and try to accommodate requests for assistance and in the exchange of data, information and resources, as detailed by interviewees in the following quotes.

"We use the Environment Agency to ask for information, they use us back."

Northumbrian Water

"[Wear Rivers Trust] and I talk quite often about project opportunities or information we could have about what we are doing, and [they] have been supporting us planning for Northumbrian Water where we will be working in the future and where the [Wear Catchment] Partnership is wanting to focus and where we [Northumbrian Water] could get better value for our investment or think about the catchment approach [referring to the CaBA] delivering investment solutions."

Northumbrian Water

From the quotes extracted from interviews with employees from Northumbrian Water, there is evidence of communication and exchange of resources with the Environment Agency and the Wear Rivers Trust. Using language such as "talk quite often" suggests quite frequent communication. By saying "they use us back" indicates a two-way, reciprocal relationship between the stakeholders, in this case, Northumbrian Water and the Environment Agency. The thoughtful communicator aims to balance their inquiry and advocacy with their fellow stakeholders (Brønn and Brønn, 2003). Inquiry engages the two parts of communication in a joint learning process, with the objective being to understand the thinking and reasoning processes of fellow stakeholders (Brønn and Brønn, 2003). Advocacy is the process of being able to communicate one's own thinking and reasoning in a manner so as to make it visible to others (Brønn and Brønn, 2003). Too much advocacy can result in one-way communication, with little feedback (Brønn and Brønn, 2003).

Balancing of inquiry and advocacy involves stakeholders telling, generating, asking and observing of one another (Brønn and Brønn, 2003), along with listening, informing, managing agreements and/or disagreements, learning together, and being open to influence and to be influenced (Scholes and Clutterbuck, 1998). The use of words "supporting", "future" and "solutions", suggest a thoughtful communication process, with positive working relationship of Northumbrian Water with the Wear Rivers Trust, now and in the future, with trust and endurance, listening to what needs to be done and

achieved from both sides, whilst bearing in-mind the larger picture of the desires of the Wear Catchment Partnership, supporting collaborative working between stakeholders.

Communication in the form of keeping other stakeholders updated with progress is key in the network. Working in partnership with other organisations requires a level of understanding from the parties involved as to where and what stage each other are up to. This may be with respect to meeting funding agreements, providing regular updates so the spending of money is monitored, and the meeting of needs is met.

> *"So you know almost all of my [Wear Rivers Trust] projects are funded by the Environment Agency, so I'm responsible for you know reporting project progress back to them and I have provided them with some financial updates as well, so with the agreements, with the funding agreements we get a set of outcomes and milestones that we [the Wear Rivers Trust] have to meet."*
>
> ***Wear Rivers Trust***

Ultimately, without frequent communication and exchange from the stakeholder(s) providing financial support and doing the work, it could be that agreements in what needs to be done would not match up, nor meet the needs of improving and maintaining the quality of the environment. Using words such as "responsible for" and "have to meet" suggests a sense of awareness and requirement from the Wear Rivers Trust in this instance, showing understanding of the importance of the tie with the Environment Agency and of their relationship with the Trust, providing funding and the need to maintain a good level of contact to reciprocate and ensure trust and continued working both ways. The implication in this context is that funding and other obligations are powerful motors on encouraging or demanding collaboration.

Good working relationships can reap benefits of creating links with other stakeholders too, expanding the network of communication and possible collaborations as demonstrated by the Wear Rivers Trust and Northumbrian Water. By developing strong, trusting two-way relationships with other stakeholders, there are opportunities to open up new working relationships with stakeholders who may otherwise have not been considered or thought about, in this case by Northumbrian Water. Making use of their community-ethos and local contacts, with farmers and anglers, for example, the Wear Rivers Trust are able to act as a bridge, bringing together local stakeholders with

Northumbrian Water; and, therefore, the possibilities of being able to manage water issues which may have otherwise not been possible.

> *"Northumbrian Water, so again they provided us with funding to deliver projects on the ground, so I [Wear Rivers Trust] provided them with updates, and also with a vast network of sort of stakeholders on the river we get a lot more back from them, we inform them of them of those issues on the river which are associated with them, and also sort of provide them with information in terms of their PR19 [Price Review 2019 – "A price review is when, together with their customers, water companies create plans for the future"* (Ofwat, 2018)*] process as well, and their investment program."*
>
> ***Wear Rivers Trust***

> *"We provide them with guidance as to where we think things need to be done, and what sorts of works can be contributed towards. It's a massive bit of work for them, and you know they are always on the phone to us asking for guidance, again I'm on the phone to them every other day."*
>
> ***Wear Rivers Trust***

Within networks, the transmission and diffusion of ideas is a key feature (Valente, 2005; Newig *et al.*, 2010). Using language such as "we inform them", "we provide them with", suggests a sense of responsibility, acting to help and inform, in this case the Wear Rivers Trust, a local-based charity informing Northumbrian Water with information they might not have otherwise been made aware of had this communicative relationship not existed. There is also appreciation here of what is important for Northumbrian Water to be informed about, "issues on the river which are associated with them", not just telling them everything, and instead information which is of use. Two-way exchange and acknowledgement of communication is key. Referring to the PR19, the Wear Rivers Trust see a place in which they can help and assist Northumbrian Water, using their local knowledge of the area. The indirect benefits of such action being that the Wear Rivers Trust are able to get their priority areas attention, and possibly highlighted for future management and funding, the latter of which is particularly important to the Wear Rivers Trust being a charity-run organisation. The regular phone conversations suggest there is recognition of the value of one-another as key players, and the importance and value of inputs into everyday work; an indication of a strong relationship. Regular contact and

strong relationships are demonstrated by other stakeholders besides the Wear Rivers Trust, for example, the Environment Agency and Northumbrian Water.

5.2. Expertise, Importance & Representation

> *"[The] Environment Agency's area team is pretty crucial to Northumbrian Water. Well the Environment Agency as an organisation full-stop."*
>
> ***Northumbrian Water***

> *"From a [Wear Catchment] Partnership perspective…I meet with at least one of the Catchment Coordinators at least once a month, if not more, and some weeks we might find that I meet several coordinators over several days, and then there might be a gap of a couple of weeks where I don't meet them. But we are pretty much on email weekly I would say, with some kind of query or some kind of support, so it might just be them wanting some information…what do we know about a certain work that is going on in a waterbody?...Most of the time it is can we represent at a partnership meeting? Can we provide an update about something that is happening at that meeting? Can we send a representative? If not, can we send someone to the next one? So, I do a lot of liaising internal within the business making sure that we are representing where we can. We are struggling for resource obviously to be everywhere."*
>
> ***Northumbrian Water***

Using the phrases "pretty crucial" and "full-stop" suggests that the Environment Agency as an organisation, in particular the area team are absolutely essential to Northumbrian Water. To keep such a strong relationship going, regular contact, be that over the phone, face-to-face or via email, is necessary. Meeting the needs and requirements of each other is important, supporting one another is expressed as an essential criterion of the link between the two organisations. Representation at meetings where and when possible is absolutely necessary in Northumbrian Water's opinion, showing interest and having someone there. From these interactions, there is a sense that organisations might not stay loyal to their original briefs, for example, attending meetings regularly at the start of a project or partnership, but drifting off as new opportunities arise.

By drawing on observations at Topsoil meetings, at the start it was very much a different set of individuals attending meetings at the start, with little continuity between the members, which was problematic in the meeting of actions and agreements made at

meetings. Individuals have also chosen to not attend certain meetings, stating they could not justify their value, and had other priorities to deal with. Continually changing attendance at meetings has affected the dynamics of the group, with the presence or indeed absence of individuals affecting what has been agreed or disagreed on. With staff moving on and leaving organisations, with high staff turnover of, for example the Environment Agency's Wear Catchment Coordinator and the Wear Rivers Trust's Topsoil Technician it has meant taking a step-back at times, going over what has already been decided, implemented and discussed. New, or indeed existing individuals can often disagree, resulting in problematic relations in partnership working.

The exchange of information via communication does not necessarily mean there are positive relationships between stakeholders, as each of the organisations involved have the ability to affect and be affected in unexpected ways by one another. For example, by the nature of the exchange or in the lack of exchange. Negative relationships can develop if the elements being exchanged do not meet the expectations of the receiving organisation, for example if an organisation requests and is told they have a given amount of data but only receive some of it. This may go on and have the potential to create animosity and thus result in the development of negative relations, for example, in cases where the provider of the information feels like they have been misinformed of the intentions of the recipient, or if the intended outcome is not fulfilled.

5.3. Challenges, Power & Temporal Changes

The challenge of lack of resources, meaning sometimes it is not possible to have organisation representatives at all meetings, or being unable to answer all data requests, and meet the needs of those seeking assistance, etc. is a challenge organisations are often faced with. Having a lack of response can be particularly frustrating, limiting ability to move forwards with a project without particular input from a stakeholder who is deemed the 'expert'. Making other organisations aware of the lack of resources, and thus inability to help is often overlooked. This can result in confusion as to whether the stakeholder organisation being asked is just blatantly ignoring requests, or whether it is in-fact the case that they are too busy and too stretched with other commitments.

> *"Sometimes opportunities do get dropped…we might think for example we have someone attending the Castle Eden meetings, part of coastal streams, we certainly did when I joined in. So, we had an operational person being involved and going to those*

meetings and I think they hadn't seen the value and we hadn't actually understood the value and weren't going but hadn't told us they weren't going, and so again it's a communication thing. But we don't have the resources as a business to represent everywhere."

Northumbrian Water

Entwined within the challenges of being unable to respond and support other stakeholders as desired is the frustrating for the recipient stakeholder. Power relations, when imbalanced between stakeholders can result in communication being withheld, and therefore, also the exchange of data, information and knowledge. Ultimately, if the organisation expecting communication does not receive it, there is potential for an element of mistrust to be introduced between the parties involved. Mistrust can result in lack of future communications, and loss of key information, data and resources being shared. This is particularly worrisome in partnership working as once trust begins to diminish it can have detrimental effects on existing collaborations.

"[T]he EA [Environment Agency], it is like trying to get blood out of a stone. Again, they are busy catchments and they [the employees] are busy…But if I want something out of you [Durham University], [you] get that sent to me today, that's not fair, but that is how it works. We're [the Wear Rivers Trust] just a little fish, and you know if they [the Environment Agency] were to stop working with us, we need to keep them sweet."

Wear Rivers Trust

"[Employee at a stakeholder organisation] is just very aloof, again some of this could be swayed by opinions, they should be more important, I mean at the start I was emailing [an employee] every week but I find [an employee] is obviously very busy, so dealing with them I try to get data elsewhere."

Wear Rivers Trust

Whilst there is acknowledgement of the fact that organisations are busy, and ultimately stretched for resources, there is evidence through the use of language used that there are elements of power at play. Referring to the Wear Rivers Trust as "just a little fish", suggests that as a charity organisation, reliant upon funding from external sources, "needing to keep them sweet" there are inherent power relations behind stakeholder working. Interviewees also expressed at a personal, individual level also suffer from feeling lower in terms of power, owing to their perceptions of their lack of knowledge and

expertise. They talked about how they feel others know more, are conscious of being "the newbie", still viewing themselves as learning, as the new starter, having to seek advice, help and guidance from the more experienced. This hints at the existence of a hidden hierarchy, or what could be termed 'imposter syndrome', feeling insufficient and lacking in knowledge and expertise, despite being sufficiently able and qualified to do the job they are employed to do.

The problem, however, is that exchange and communication that are not reciprocated can result in the weakening of the strength of relationships. By going elsewhere for data means going beyond stakeholders who are 'experts' in the catchment area, who have datasets that may be more detailed and more relevant over space and time across the catchment. However, as detailed by an employee from the Wear Rivers Trust, they do acknowledge the constraints on statutory bodies.

> *"And it is going to be an ongoing pressure as money is made tight. I mean it is hard for us to secure it, and statutory bodies are being asked to make cuts again."*
>
> ***Wear Rivers Trust***

Uncertainty can have potentially damaging consequences for employee morale, and in some instances may result in staff leaving, finding employment elsewhere. This is of course not saying pressures always result in staff leaving and is merely a suggestion of one possible outcome. However, when staffing changes do occur, regardless of the reason for change, it can have detrimental effects on the workforce and functionality of the organisation, affecting the strengths of relationships organisations hold with one another.

Ultimately, when staff leave, they take with them their knowledge and expertise, along with their contacts with other organisations. A number of interviewees described how their contacts in organisations such as the Environment Agency and Natural England allow them to gain access to others through the use of contacts of their contacts. In the case of Natural England, they are able to provide links to local landowners. An example from an interviewee from Durham County Council talked about how they had worked with the Wear Rivers Trust and was able to put the Trust in contact with contractors with whom they could work with to complete some river-restoration works. By the Trust making use of their contacts at the Council they were able to gain expert knowledge and assistance, including advice on the written scheme of investigation and who best to work with. Interviewees from the Wear Rivers Trust and Northumbrian Water in particular

talked about the importance of their links with Durham University, describing contacts they hold as "useful names" to have, with their expertise linking to wider research projects beyond the University, potential funding sources, as well as to student projects and research within the University. Through the overarching Rivers Trust, interviewees from the Wear Rivers Trust discussed the importance of their links with one another, and how through their relationship, they are able to build relationships with other stakeholders, for example contractors.

The Wear Rivers Trust provide also plays an important role in putting others in contact with relevant organisations. One interviewee from the Trust described how they are positioned well within the local community, having good relations with local landowners. Familiarity and rapport with locals are important in people being able to approach the Wear Rivers Trust for example if they spot a pollution issue on a river, or something that they are concerned about in the river environment. The Trust is then able to sign post the problems and concerns onto relevant organisations, including the Environment Agency, Northumbrian Water and Durham County Council, to be resolved.

Contacts individuals have are also of great importance for ensuring input in the management of water resources from stakeholders of all levels. Within the Wear Catchment, a number of organisations including Durham Heritage Coast and the Wear Rivers Trust hold important outreach contacts, linking with research at local universities, as well as in educating local communities and schools about the river environment and the management of it. The Wear Rivers Trust have educational and outreach links with Northumbrian Water in projects involving their staff, volunteering in projects as a means of giving back to and supporting the local community. The Wear Rivers Trust also hold outreach beyond the Wear Catchment, holding links with the Tees Rivers Trust and West Cumbria Rivers Trust. By having links with other Rivers Trust, the Wear Rivers Trust is able to share and develop ideas regarding the protection and management of the river environment.

An example of an outreach and volunteering project that the Wear Rivers Trust is responsible for in the Wear Catchment is Riverfly monitoring, supported by the Freshwater Biological Association who provide training. Through the recruitment of local volunteers who are responsible for surveying a section of a river, the Trust are able to gather data on the water quality of the river, which they can send to the Environment Agency. These data are subsequently used towards assessing the status of the quality of

the River Wear and its tributaries, and in identifying where the Wear Catchment is in achieving the goals of the WFD.

Working with young people and schools in the catchment is important in ensuring sustained protection and management of the rivers. Alongside Riverfly monitoring, the Trust also assist with a number of community and volunteering tasks hosted by other organisations, including Durham University's student Conservation Society, and tasks led by Durham Wildlife Trust. The Wear Rivers Trust also do joint volunteer projects with Groundwork North East and Cumbria, and the Rivers Trust. It is intended that by coming together on joint tasks, costs can be kept down, with the additional benefit of a larger volunteer task force than if only a single organisation hosted the event. During large organised litter picks, the Wear Rivers Trust discussed in interviews how they have been successful in attracting local businesses in supporting the task, namely Greggs Plc., who provided volunteer refreshments as well as staff volunteers to join in with the task. Having such links with local businesses are an important source of external funding, and a way of enhancing participation from organisations outside of the scope of river management.

Ultimately, communication and exchange are the foundations of the links between the stakeholders in the network, facilitating activities, management actions and the growth of knowledge and awareness of water issues in the catchment. The ways in which the stakeholders interact with one another can affect the resulting opinions, attitudes and actions happening across the catchment in relation to the management of water resources.

5.4. Strength of Relationships

In network analysis, the consideration of the strength of ties is important (Granovetter, 1973). Be they weak or strong ties, both are advantageous and restrictive to the functioning of the network. The balance of strong and weak ties is therefore seen to be indicative of the nature of the network. Strong ties indicate the ability of stakeholders within the network to influence one another, as well as, share views, offer support, communicate effectively and have mutual trust. However, strong ties can be problematic in that they typically exist between groups that are similar, which can result in a tendency to get locked into ways of thinking, potentially leading to cognitive blocking (Messner, 1995) and group thinking (Janis, 1982).

In contrast, weak ties are associated with less frequent communication, or with communication with those outside of the central network. Weak ties can, however, be advantageous because they can be between more diverse individuals; therefore, meaning more diverse information can be exchanged (Newig *et al.*, 2010). Too many weak ties in the network can result in the network becoming vulnerable, because weak ties are easily broken and may be lacking in trust between the parties concerned.

In the Wear Catchment network, the stronger ties are associated with those stakeholders who come together in partnership working. It has been suggested in network analysis theory that the strength of ties in a network are likely to be affected by a linear combination of time, intensity and reciprocal services (Granovetter, 1973). Stakeholders with strong ties can be those who have known and worked together for long periods of time, with an awareness of and appreciation for one another's working behaviour, and how best to interact and communicate, for example, face-to-face, over the phone, via email, are all important in creating stronger relationships. Interviewees who used language such as "close relationship", suggests the existence of long-standing and/or strong working relationships, and thus strong ties.

> *"[The] EA [Environment Agency] …they have given us a lot of funds overtime, and I have the closest relationship with them through my role [in the Wear Rivers Trust]."*
>
> ***Wear Rivers Trust***

> *"We [Northumbrian Water] do work closely with the Environment Agency Catchment Coordinator so they provide support to the [Wear Catchment] Partnership but also to us as an organisation."*
>
> ***Northumbrian Water***

> *"At the moment as a business we work quite closely with the [Durham] County Council. We work with them in terms of managing some of our assets and working on flooding, so we have our flooding problems and they have theirs, and sometimes they join, so that partnership working is quite advanced for that really leaning directly into the Wear Catchment Partnership."*
>
> ***Northumbrian Water***

As discussed in Chapter 4, at the centre of the Wear Catchment network, there is a group of stakeholders at the centre of the network who resemble the inner circle of the strongest

ties. These ties albeit strong ties, do have some level of flexibility, with the relative strength of the tie changing depending on the level of interaction between the stakeholders, for example, during different stages of partnership and project working. As stakeholders go through different phases of working, improving, adjusting and developing their understanding, expectations and ability to act and react to changes within the catchment system, and both in and outside of the organisation, stakeholders may change their relationships with other organisations.

The strongest relationships are those that remain present and productive over time, taking many forms, whilst enduring change through new interactions and exchanges, thus supporting the point made by Granovetter (1973), that relationships can change and strengthen overtime. In the case of partnership working, partnerships sometimes open up possibilities for the creation of more and stronger ties between otherwise unconnected stakeholders. By giving a platform, place and purpose for interaction there is also the opportunity for existing relationships to also strengthen.

"So, yeah, the Environment Agency, from a [Wear] Catchment Partnership perspective, from our perspective as Northumbrian Water, it is the information they hold and the power they have, they are probably the most important [stakeholder]."

Northumbrian Water

"DCC [Durham County Council] are pretty influential, but again I don't suppose they realise how influential they could be within the project, but they have been incredibly supportive."

Northumbrian Water

"Sunderland [City Council] are not as important as they could be. I think I would rank them more lowly, but actually I haven't revised them because I hadn't thought from the perspective that they manage the local delivery groups, they are probably more important at the lower level than they are at the steering group level."

Northumbrian Water

Weaker ties are with stakeholders who are albeit just as important, are those who are not directly involved in partnership working at all or over a continued period of time, i.e. they

are occasionally involved in meetings, for example. Referring to points made by the Wear Rivers Trust, they currently hold weak ties with Durham Wildlife Trust and Sunderland City Council. Both organisations operate in the Wear Catchment, however, neither are greatly involved in current partnerships or projects in the Catchment; but is something the Wear Rivers Trust are keen to change in the future, developing stronger integrated working relations with them both. Greater engagement, involvement and project input with Groundwork North-east and Cumbria is something Northumbrian Water is also keen to explore.

"DWT [Durham Wildlife Trust], another catchment partner, we have approached them on a number of occasions with project partnership opportunities, but they haven't taken them forward as of yet."

Wear Rivers Trust

"SCC [Sunderland City Council] …they are harder to engage with, but [the Wear Rivers Trust] are keen to."

Wear Rivers Trust

"I put in Sunderland [City Council] but that is probably more from an organisational perspective, so I have never met one [referring to Sunderland City Council employees] of them more than once across the table. I know them to speak to, and into the future they [may] be more important, but at the moment we have not developed those relationships."

Northumbrian Water

"Groundwork. As an organisation we have very good relationships with them. We do lots of corporate works together, corporate projects, but from a catchment perspective we sit around the table and going forwards they will be more important to us as a partner I think."

Northumbrian Water

In these interview quotes, both the Wear Rivers Trust and Northumbrian Water describe their future desires for working with organisations with whom they currently hold relatively weak relationships with. Using language such as, "approached them", "are keen to" and "into the future" all indicate positive thoughts. However, if, when and how exactly these organisations will come together and work on future projects remains unclear. An

employee from the Wear Rivers Trust expressed ideas why engagement with Sunderland City Council may not be feasible in the current state of the organisation.

"…we have a lot more difficulty engaging with Sunderland [City Council] than we do with Durham [County Council]…The teams at Sunderland are smaller than they are at Durham, and I think it's down to individuals, department culture…So Durham seem more open to outside input whereas the Sunderland people seem to have less space to talk about things that we can help them with. So, you know, we continue to make efforts to gain more influence and access to Sunderland with some limited success. Personal relationships with actual officers are good, but they don't seem to be so open as Durham. We do have significant relationships with a number of [Durham] County councillors. But we [the Wear Rivers Trust] don't know any Sunderland City councillors particularly [well], which is a gap. But we don't actually use the County councillor relationships to make contact with officers that is just done on a professional basis. So, whilst the gap with Sunderland [exists], it is an avenue I would use if I had relationships with City councillors, it is not something that have had to do with Durham County."

Wear Rivers Trust

As detailed in the quote above, the strengthening of ties with stakeholder organisations is ultimately dependent on individuals' actions. If people within the organisation, that another stakeholder organisation wants to engage with do not take interest, see the worth of a project, or simply do not have the resources to be able to partake, this affects the likelihood of the development of stronger working relations. To gain greater communication and exchange with organisations it is sometimes necessary to get past the 'gatekeepers.

"[Employee] at the Coal Authority. Well he has just been a gateway into the Coal Authority because I deal with other people in there in terms of data, but he is the one that hurries it along. He is a facilitator."

Wear Rivers Trust

"[Employee at the Wear Rivers Trust] is also a key contact, so if it is something more technical, I speak to [employee at the Wear Rivers Trust] first and then probably do directly to [employee at the Wear Rivers Trust]. So [employee at the Wear Rivers Trust] is the one that provides information and vice versa. If [employee at the Wear Rivers Trust] is working on something and wants an answer to something and wants an

answer to something [they] don't necessarily go through [employee from the Wear Rivers Trust]."

Northumbrian Water

Change in job roles of individuals, whether leaving their current organisation or moving up in the hierarchy to more responsible roles can, however, have detrimental effects on the relationship's organisations have with one another. If an individual leaves their position in an organisation, they may take with them their contacts, breaking once strong existing ties. Or, if an individual moves higher in their organisation they might have bigger work commitments, limiting the time they can spend on a project.

"I only work two and a half days a week, so it is difficult to fit everything in…There is always people you should have and could have more contact with, but it comes down to time. There's probably more scope for working with Northumbrian Water, and possibly the Environment Agency, and I'm sure with other groups, such as the Rivers Trusts, but it is just it is always that things get pushed down."

Wear Rivers Trust

"I think that the University does not represent terribly well in the [Wear Catchment] Partnership. So quite often we will have a steering group and the university does not come, and if they are there is might just be that they have sent you there as a researcher, that's not quite how we see the University's role in the Partnership. We think they should be representing better and also taking that back into the organisation and thinking about how they can work with that."

Northumbrian Water

Focusing on the latter part of the quote from Northumbrian Water, referring to the desire for better representation from the University highlights the different institutional cultures of stakeholder organisations. Northumbrian Water as a business are striving towards profit-making, and keeping the customer happy, whose main focus is on the treatment of wastewater and the provision of safe drinking water. Durham University on the other hand are seeking to achieve and maintain their high-ranking in league tables as an education provider and research institution, whose priority is not solely on one aspect of research. Northumbrian Water would like better University representation, but the University is not only interested in the water environment, and the management of water

resources. Water is merely part of the research being undertaken by the Geography Department, and representation at everything is simply not feasible.

However, it is important to note that there are instances in which there are weak ties, not because of a lack of communication, exchange and commitment from stakeholders, but as a result of there being little or no need for continued engagement. Instead, some stakeholders only have contact from time-to-time. A number of people interviewed talked about one-off conversations with stakeholders, but still valued their input enough to list them as a contact organisation they work with in water-resource management in the Wear Catchment. The Wear Rivers Trust offer support to Durham County Council, local residents, farmers and anglers, and is contact and support which is ultimately dependent upon the conditions of the rivers in the catchment. The Wear Rivers Trust act as a 'bridging stakeholder organisation' to other stakeholders who are more suitably placed to help in terms of the data, information and knowledge they hold, and the support they can offer.

> *"NPAONB [North Pennines AONB], it's a lower ranking for my contact, but it doesn't make it a lower importance"*
>
> ***Wear Rivers Trust***

> *"DCC [Durham County Council], a lot of their work involves stakeholder engagement, so if they have anything happening on rivers they often come to us and we can point them in the direction of who they need to talk to, you know angling clubs, local groups, groups who have helped us, landowners, we can provide them with support."*
>
> ***Wear Rivers Trust***

> *"Farmers, anglers, local residents, they get in touch with me to inform me about what is going on, and then I can take it to the relevant organisation and do something about it. So, it is mainly the EA [Environment Agency], or Durham County Council. That is very much what we encourage our local people to do, to get in touch with me to signpost the issue onto the relevant organisation."*
>
> ***Wear Rivers Trust***

A key element in being able to maintain such connections is through trust. Trust can be defined as: "essential for stable social relationships" (Blau, 1964: 99). Ultimately, if the trust is broken between the stakeholders that is with reference to any strength of tie it

can result in a breakdown of communication, exchange, and therefore the benefits and contributions that stakeholders may be willing to share to the Wear Catchment Partnership. Golembiewski and McConkie (1975) state no other single variable influences interpersonal and group behaviour as does trust. When destroyed, there is potential for communications to falter and collapse (Bok, 1978). Even for the most everyday interactions, trust is vital for cooperation (Lewis and Weigert, 1985). When trust exists between two or more parties, it is generally that there is willingness, which is not forced, cooperation between them, and the benefits result from that cooperation (Tone Hosmer, 1995; Pirson and Malhotra, 2011). Referring back to the quotes, through use of language, such as: "they often come to us", "can provide them with support", and "get in touch" support this existence of trust between the stakeholders, in this case, between locals, and the public, private and environmental voluntary charity sectors.

5.5. Assessment of the Current State of the CaBA in the Wear Catchment Based on the Thematic Analysis of Interviews

Referring back to the CaBA (introduced in Chapter 1), the purpose of this section is to draw on the analysis of the interviews conducted in this research to base an assessment of the current state of the CaBA in the Wear Catchment. Through the analysis of interviews, there is evidence of stakeholders working to localise environmental improvements, together as opposed to working individually, using the strengths of one another, making use of contacts, knowledge and expertise, and in the sharing of ideas. A number of individuals highlighted collaborations their organisation has with a wide range of stakeholders in decision-making processes, keeping one another informed, identifying issues and potential outcomes and actions on how best to manage the water environment together.

The Wear Rivers Trust is keen to encourage the continued input and involvement of locals in water-resource management, linking to the desire for a community led-approach in the management of water resources in the Wear Catchment through the CaBA. However, at the moment, there is little sign of the involvement of the local communities, with a lack of representation at the Wear Catchment Partnership meetings, for example. The only evidence of the involvement of local communities is through the use of local knowledge and expertise, as discussed and highlighted in the interviews.

5.6. Summary

Chapter 5 provides a thematic analysis of the interviews conducted with representatives from stakeholder organisations involved in water-resource management in the Wear Catchment, expanding on the SNA in Chapter 4, further developing awareness and knowledge of the relationships between stakeholders. The chapter has addressed a number of themes. Topics of discussion include, the exchange of data and/or information between stakeholders, the balance of giving and receiving of time, data and information between stakeholders, and the support offered by stakeholders to others. Linking to these topics are the broader themes of trust, reciprocation, and the challenges associated with power and hierarchy. From analysis of the interviews it is clear that some stakeholders hold relatively greater influence in catchment-management than others. Themes emerging from the analysis of interviews also indicate the existence of a feeling of 'imposter syndrome' by some, and challenges of hierarchy prevalent in some instances.

Chapter 6 – Agent-based Modelling

In Chapters 4 and 5, the relationships and purposes of interactions of stakeholders working in water-resource management in the Wear Catchment were explored through a social network-based analysis and in-depth analysis of empirical data from interviews. So far in this research through the analysis of the network and interview data, insights into the system have been reliant on the use of words, descriptions, opinions and observations of the stakeholders, producing a snap-shot in time of the state of the management of water resources in the Wear Catchment. To add an additional level of understanding, and to explore further the dynamics of the system and to consider how it may function in relation to decision-making and the wider context of collaborative working, more specifically, the CaBA, ABM was used to explore stakeholder behaviour further. By using ABM, it is possible to test a range of scenarios, assessing potential changes, and thus the resultant impact on the functioning of the catchment-management system.

As shown and discussed in Chapters 4 and 5, the exchange of data and/or information between stakeholders is extremely important in catchment-management. Using the information gleaned from the interviews and their analysis in Chapter 5, it is apparent that factors including stakeholder resources, specifically time and workforce, as well as time delays in the delivery of data, which may be introduced due to competing workloads, have the potential to affect the process of data sharing between stakeholders. Therefore, to enhance understanding and knowledge of what could happen were there to be changes made to stakeholder resources and in response times in the Wear Catchment network to the delivery of data, an ABM was created with specific reference to the delivery of data to the Wear Catchment Partnership. In the wider context it is intended that the ABM could be used by stakeholders to model potential future scenarios of change to determine what could happen if they were to change their behaviour in data sharing.

ABM offers a tool for exploring network dynamics, focusing on the creation and dissolution of network ties between agents. By combining network science and simulation models, in this case, ABM, it offers a means of being able to understand how networks form and could evolve and change, and how features of those settings, such as diversity and segmentation impact on the process. Social models such as ABM have begun to be used in environmental disciplines, with the intentions of being able to describe and predict the ways people (stakeholder organisations in this research) are likely to behave

in response to different stimuli given various decision rules (Prell *et al.*, 2007). One example of a computational framework which can be used to underpin the design and implementation of agents is the Belief, Desire, Intention (BDI) framework (e.g. Herzig *et al.*, 2017).

In this research, the modelling process focuses on the interactions and reactions of stakeholders in the acquisition of data to support decision-making in water-resource management. By combining empirically based knowledge of stakeholders from a networked perspective of the Wear Catchment, it is possible to model potential decision-making processes of the stakeholders in the acquisition and delivery of data, incorporating behaviours such as response times to requests. Ultimately, the modelling process allows for the exploration of the influence and combination of stakeholder behaviours and strategies.

In addition to the use of the network analysis and empirical findings, incorporation of observations from meetings are beneficial to being also included in the model. A common feature of all social research is participation (Atkinson and Hammersley, 1994). No matter the research, the researcher at some point enters the world of the groups or people being studied in order to develop understanding of the phenomena of interest, which in this research was the interactions between stakeholders involved in water-resource management in the Wear Catchment. By attending meetings with stakeholders, it offered key insights into their ways of working, i.e. how delays in the delivery of data to the Wear Catchment Partnership may be introduced, for example. Although not fully immersive participant observation, by observing in more detail the dynamics, relationships and interactions between the stakeholders in meetings, it allowed for a better understanding of the issues, pressures and processes taking place in water-resource management in the Wear Catchment.

6.1. Background to Agent-based Modelling

Agent-based simulation is one type of computer-simulation framework that has been used by some sociologists to explore the intermediate complexity of the world. The agent-based framework can be used to flexibly represent our conceptual models of discrete, multiple, multi-faceted, and heterogeneous actors (be they humans, organisms, institutions or any other entity that pursues a goal), and their interactions and relationships between one another and with their environment, through space and time.

In their simplest form, an agent is an individuated object with unique defined attributes, (e.g. location, sex, aspirations) capable of carrying out context-dependent functions that may result in changes to their own attributes and of others, for example, whether to interact with someone based on the level of trust with them.

A key element of the ABM philosophy is that the basis of complexity in the system is seen as a result of individual actions. Understandings of this element of ABM relate to the ideas of generative social science, whereby larger-scale structures are believed to be emergent from a range of smaller-scale interactions (Epstein, 1999). In the context of this research, the effects portrayed in the model are representative of the actions or behaviours of the stakeholders, constrained by the knowledge and information collected from stakeholders, the analysis of the network of stakeholders working in the Wear Catchment, and empirical data from interviews, as well as the contextual effect of the wider social system.

Based on the Partnership working involving a core group of stakeholders along with external pre- and post-meeting communications such as via telephone, email and face-to-face interactions in the workplace or in sub-meetings, the model aims to represent the behaviours of stakeholders in the acquisition and delivery of data to assist with the management of water resources. It is the culmination of the stakeholders' decisions (behaviours) at the smaller micro-scale, along with the effects of larger-scale macro-systems, such as the working practices and beliefs of the organisations that determine the outcomes, either constraining or enabling the behaviour of the stakeholders in the system. Strategies of data acquisition for each of the core stakeholders were drawn up using the network and empirical data collected from stakeholders. The strategies represent the behaviours of the stakeholders in relation to the processes they follow in acquiring data they desire and need. One of the benefits of using a modelling approach is to explore the possible interactions and subsequent effects of combining multiple stakeholder strategies.

Owing to the basis of the ABM in this research being the empirical data collected from qualitative interviews, of primary importance was the translating of the qualitative information from 'actors' (stakeholders interviewed) into rules relevant to 'agents' (representing the stakeholder organisations) in the ABM (Rousevell *et al.*, 2012). Philosophy for the transformation of qualitative data into an ABM is covered in the work of Agar (2003), Yang and Gilbert (2008) and Zellner *et al.* (2014), who support the change within the system conceptualised on logic-based functions, ideas captured and elicited

from empirical data that need to be converted into coded rules, or as Agar (2003: paragraph 1.3) describes it, "[to] make numbers out of words". Successful studies have been carried out combining empirical data and modelling, for example, see Altaweel *et al.* (2010).

The conversion of empirical data into rules for ABM has been argued to be a potentially subjective, controversial process that can be messy or inaccurate, especially in cases where behaviours are to be represented in the model using definite and accurate numbers. To account for potential subjectivity and controversy, conceptual thresholds can be incorporated into the model design. Conceptual thresholds, represented as a number, define the point at which important change(s) happen in the system being represented in the model, and form a central component in translating data into the model. As Zellner *et al.* (2014: 2) state, an important thing to bear in-mind when creating a model is that:

> *"Since a model is not meant to replicate what a change of behaviour feels like or means for a person, but rather to replicate the process and result of behaviour change, using thresholds that are valid in a "more or less" sense is appropriate."*

6.2. Model Implementation

In this research, NetLogo (Wilensky, 1999) was used to create and run the ABM. NetLogo is a widely used modelling platform and language, that is used for modelling multi-agent systems (Wilensky and Rand, 2015). Other modelling languages exist, including Swarm, Repast and Mason; and other modelling platforms exist, including, Ascape, Breve, Cormas, MASS and SeSam. The arguably simple language of NetLogo, and free to use software, as well as, its international popularity amongst scholars in the field, from natural and social sciences backgrounds made it a suitable choice for use in modelling in this research. For this research, owing to the availability of support, including training courses, textbooks, and online tutorials and resources, NetLogo was deemed to be the most appropriate modelling language and platform to use.

In NetLogo, the agents are able to perceive their environment and act upon the conditions of it, carrying out their own actions, and are autonomous. Every model in NetLogo contains three main elements, which are:

1. **Patches** – patches are stationary 'agents' or components of a grid;

2. **Turtles** – agents that are able to move around and interact with one another and the patches; and
3. **Observer** – the controller of the experiments carried out using the model.

Within the turtles and patches, different types of agent can be defined, referred to as 'breeds', which have their own user-defined variables, allowing for agents to hold their own state, and patches to have multiple attributes. Through the use of primitives, which are pre-programmed functions, the behaviours of agents can be controlled by commands, such as 'ask' that asks the agents to execute procedures in the modelling process, for example. To visualise the system being modelled, outputs can be produced through the creation of charts, graphs and tables.

6.3. ODD Protocol

The standard protocol that is used to describe simulation models, including agent-based models is the Overview, Design concepts, and Details (ODD) Protocol (Figure 6.1). The ODD was developed and introduced by Grimm *et al.* (2006) so as to provide a universal structure for describing models, making them easier to understand and to duplicate (Grimm *et al.*, 2006).

	Elements of the ODD protocol
Overview	1. Purpose
	2. Entities, state variables, and scales
	3. Process overview and scheduling
Design concepts	4. Design concepts - Basic principles - Emergence - Adaptation - Objectives - Learning - Prediction - Sensing - Interaction - Stochasticity - Collectives - Observation
Details	5. Initialization
	6. Input data
	7. Submodels

Figure 6.1: Overview of the ODD Protocol for describing ABMs (Railsback and Grimm, 2012).

6.4. Decision-making Theories in ABM

In an ABM, theories about the decision-making processes are important to consider in the conceptualisation of the agents. In socio-ecological systems, it is traditionally assumed that actors follow patterns of the standard model in economic theory of the 'selfish rational actor' (e.g. Godelier, 1972). The selfish rational actor has perfect knowledge, stable preferences and makes calculations in an attempt to make decisions that will maximise their utility.

In relation to modelling agents, bounded rationality, is the most recognised and understood of decision-making theories. Bounded rationality considers that individuals deviate from rational decision-making, because they are bounded by cognitive limits, along with lack of information and finite willpower, especially in circumstances of solving complex problems. Decisions can be complicated by a number of aspects of human behaviour including heuristics, mental models, pro-social behaviour, rules of thumb, status, learning, interaction, habits, altruism and self-identity, meaning people do not always choose the most 'profitable' option when faced with several choices.

In this research, it is acknowledged that each of the stakeholders is bounded by elements including lack of knowledge, limited cognition and complex behavioural and cultural influences, be they of the individuals who work in the stakeholder organisations, or the beliefs of the organisations themselves as a whole. Theories of agent behaviour were not otherwise formalised in the model in this research. Bounded rationality, along with related theories such as planned behaviour was used in the assumptions made about the ways in which the agents interact. The theories were also applied in the writing of the rules of interaction of the agents and their decision-making.

6.5. BDI and FIPA

Conceptualisation and theorisation of the agents' behaviour into the structure of the model was achieved using a BDI approach. Originating in artificial intelligence (Bratman, 1987), the BDI approach can be used as a system to symbolise rational agents with particular mental attitudes. These attitudes represent the information, motivation and deliberation phases making up an agent's decision-making processes (Rao and Georgeff, 1995).

According to Bordini and Hübner (2006), the BDI approach is important in multi-agent research linking to the ideas of the Procedural Reasoning System (PRS). In the PRS, an agent perceives its environment, from which it deliberates to choose an action, which subsequently results in the execution of intentions, representing the agent's reaction to the original environmental conditions (Myers, 1997). BDI has been applied in a number of modelling languages, including NetLogo (Bordini and Hübner, 2006; Sakellariou *et al.*, 2008). In this research the NetLogo extension developed by Sakellariou was utilised to incorporate BDI into the model and to develop the complex reasoning capabilities of the stakeholder agents.

In BDI, a belief can be defined as representing the agent's understanding of the world. As the environment of the model changes, which the agents subsequently sense, along with communicating with other agents the beliefs of the agents can be updated and changed. Ultimately, beliefs are used so as to inform the actions the agents take. Action of the agents are represented by intentions. Intentions describe the intended action of agents as well as a checkpoint at which a particular action should end. Within the modelling process, intentions are stored in a stack, which means that agents can have multiple aims they want to achieve at once, but these aims can be affected by other agents in the model and the model environment.

An important aspect of the BDI system is communication between the agents. However, there is no detailed communication system present in the basic NetLogo language. An additional library has however been created also by Sakellariou *et al.* (2008). This library contains primitives that assist with the sending and receiving of messages between agents, which is based on the FIPA-ACL system (The Foundation for Intelligent Physical Agents – Agent Communication Language) (FIPA, 2002). Therefore, alongside the BDI library, the message-passing library was also used in the modelling process in this research. It is important to note that neither the BDI nor FIPA-APL messaging functions have been widely applied in socio-ecological modelling, therefore this research provides an opportunity to demonstrate and thus evaluate their use, in this case with respect to the modelling of the interactions of stakeholders working in water-resource management at the catchment-scale in the context of the case study in the Wear Catchment, specifically the Wear Catchment Partnership.

6.6. Model Verification and Validation

In the creation of any model, it is important to take into account the processes of verification and validation (Crooks *et al.*, 2008). As North and Macal (2007) suggest, by carrying out and completing the processes of verification and validation, the model is transformed from being a toy to a tool, i.e. it can be used in applications to test and challenge hypotheses. The process of verification assesses how well the implemented model compares to the conceptual model, and validation assesses how well the implemented model compares to the real-world. Even though absolute verification and validation are argued to be impossible (Refsgaard and Storm, 1996), it is through the carrying out of the processes of verification and validation that gives confidence to the modelling process and also to the ability of the user in being able to use the model for its intended purpose (Rand and Rust, 2011).

With reference to ABM, the process of verification involves the checking of the model against the ODD Protocol, i.e. comparing what the model does to what it is expected to do. Through the commenting (annotating) of the model code in the model creation process, it is also beneficial in the verification process, so that even an inexperienced modeller can understand which parts of the code refer to which ideas in the conceptual model, in the case of ABM, the ODD Protocol, and associated diagrams, for example, in this research the stakeholders' strategies (Gilbert, 2000). By comparing what happens when implementing the code to what is expected, it is possible to identify bugs and inconsistencies in the code. By checking the code section by section, it is also possible to join components of the model to create a more complex model. Through this process of code checking, the model in this research was partially verified.

The validation of the model involves an assessment of the extent to which the model is representative of the real-world system being modelled (Casti, 1997). According to Rykiel (1996), there are three core ways of validating: (1) whole-model validation which involves the comparison of model outputs to observations of the real world; (2) conceptual validation, which involves evaluation of theories, ideas and assumptions that underpin the model; and (3) data validation which involves evaluation of the inputs into the model. Rand and Rust (2011), support the need for just three stages of validation: (1) face validation, which involves conceptual validation of the model; (2) empirical input validation, relating to the correspondence of input data to the real-world; and (3)

empirical output validation, involving comparison of the model outputs to real-world data. In this research face and input validation were the main focus. Due to there being no predictive element of the modelling, empirical output validation was not considered.

Important aspects of input validation are sensitivity analysis and model calibration. Sensitivity analysis involves the analysis of the influence of certain model parameters, and by adjusting parameter values it can be used to calibrate the model, as well as to conduct experiment scenarios.

6.7. Ethical Considerations in ABM

As with any type of research involving human participants, it is important to consider the ethics of the research. Further to the ethical considerations detailed in Chapter 3, ethical considerations were made in the context of the agent-based modelling. In modelling, the researcher is creating a model that is attempting to be representative of a real-world system, and the case of this research includes the representation of stakeholders and their interactions with one another. Ultimately, unethical modelling could have harmful consequences on the subjects represented in the model. The specific ethical issues that were considered in this research, and therefore accounted for were:

1. Transformation of data into the model

Through the use of data from interviews to inform the rules for the behaviour of agents in the model, there was a need to consider the potential for misunderstanding what was said in the interviews. Therefore, the signing of informed consent of the participants at the start of interviews was of great importance. Participants were reassured that they would not be able to be identified from their personal contributions if used in the creation of the model.

2. Representation of agents in the model

With modelling of stakeholder organisations there is the possibility that actors may agree or disagree with their representation in the model. Although difficult to eliminate all potential disagreements, by representing stakeholders in the model as organisations rather than individual people or teams, the potential for disagreements was reduced. By collating responses from a number of interviews with individuals from organisations, to represent the organisation as a whole in the model it increased the likelihood that the

resulting representation was one of greater consensus than would otherwise have been the case.

3. Communication and dissemination of outcomes

It is important to be clear on the purpose of the modelling in the context of the research being conducted. In the case of this research, modelling outputs in the form of experimental outputs, including modelled future scenarios of change will be provided to stakeholders. However, it is intended that the model outputs will be used solely to start discussions and are not a definite representation of how things will turn out in the future with regards to water-resource management in the Wear Catchment, in particular the functioning and future workings of the Wear Catchment Partnership.

6.8. Stakeholders in the ABM in the Wear Catchment

The ABM in this research is based on the interactions of stakeholders who are part of the Wear Catchment Partnership. Based on evidence from Chapters 4 and 5, and also from email communications relating to the Wear Catchment Partnership, four key stakeholders of the Partnership were identified and are included in the ABM. The four stakeholders are, the Wear Rivers Trust, the Environment Agency, Northumbrian Water and Durham County Council.

In the model, stakeholders are involved in acquiring four types of data and delivering it to the Wear Catchment Partnership. All of the data are considered important in being able to assess and monitor the quality of water. The data listed are supplied by the Wear Rivers Trust (WRT), the Environment Agency (EA), Northumbrian Water (NW), and Durham County Council (DCC) respectively, and are:

1. Ecology data (referred to in the model as ecology data);
2. Surface-water and groundwater quality data (collectively referred to in the model as water quality data);
3. Assets and pollution data (collectively referred to in the model as assets data); and
4. Land-use, land ownership and planning data (collectively referred to in the model as land data).

The following sections outline the basis of the ABM, detailing: the factors influencing stakeholders' decisions using information gleaned from the interviews conducted in this research in the context of water-resource management in the Wear catchment; the

strategies followed by stakeholders in the ABM; and components of the model. An ODD Protocol is also provided for the ABM.

6.9. Factors Influencing Stakeholders' Decisions

In general, factors influencing decisions include motivations and goals of the stakeholders with reference to the acquisition of data, such as perceptions of where best to acquire data, whom they trust, and who they work well with. Stakeholder decisions are also affected by the stakeholder's overarching organisational beliefs, the influence of policy, and access to available resources. In this research, owing to the data and knowledge acquired from the surveys and interviews, and their analysis, the factors influencing stakeholders' decisions in the ABM are the availability of resources, specifically time and workforce resources. Time resources refers to the time that the individuals within the stakeholder organisations have to complete the task in hand, i.e. the percentage of their working hours, assuming that they work 36 hours per week, to carry out the request for data by the Wear Catchment Partnership. Workforce resources is a measure of efficiency at which the stakeholder organisations can carry out the task of delivering data to the Partnership, i.e. 50% would represent that the stakeholder organisation is only able to carry out the task with 50% efficiency.

6.10. Stakeholder Strategies

The strategies developed for each of the stakeholders in the model, namely, the Wear Rivers Trust, Northumbrian Water, the Environment Agency, and Durham County Council, using the evidence from the surveys and interviews, and their analysis, are presented in Figures 6.2 and 6.3. The stages included in each of the strategies include: observing the task in-hand, i.e. what data is to be acquired; whether or not the stakeholder can fill the role of a data acquirer, i.e. do they have sufficient resources; and then taking the data to the Wear Catchment Partnership. The model runs for 480 hours equating to the average working week of eight hours per day for three months, with three months being the average time between Wear Catchment Partnership meetings. If the stakeholder delivers 100% of their data to the Partnership before 480 hours, they no longer receive requests for data, and have completed the task in-hand.

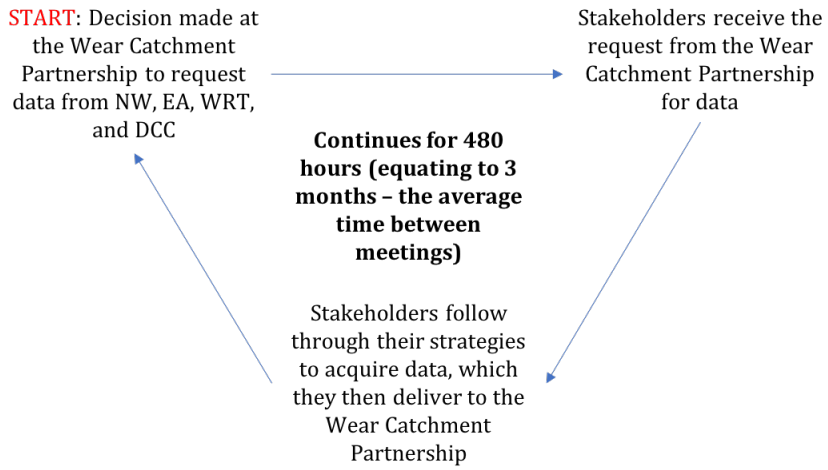

Figure 6.2: Wear Catchment Partnership ABM strategy.

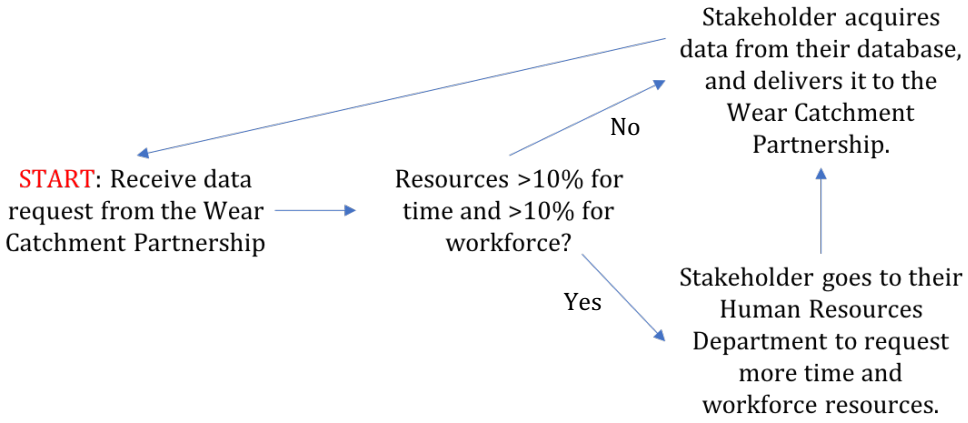

Figure 6.3: Stakeholder's ABM strategy.

6.11. Components of the Model

The premise of the modelling process is to explore the interactions between stakeholders and the Wear Catchment Partnership working in the Wear Catchment to acquire data to assist in the management of water resources. The key questions the modelling aims to address are:

1. How might stakeholder's time and workforce resources affect their ability to acquire data for the Wear Catchment Partnership to assist with the management of water-resource issues in the Wear Catchment?
2. How might delays, such as in responding to data requests affect the delivery of data to the Wear Catchment Partnership?

6.12. Wear Catchment ODD Protocol

The ODD Protocol (Grimm *et al.*, 2006) is used in ABM to describe the details and concepts of the modelling being undertaken. Following through the ODD Protocol (Figure 6.1), the following sections detail the elements of the model based on the strategies developed for the stakeholders in the Wear Catchment. Where the courier font is used, reference is being made to the names or elements of code directly included in the model.

Overview – Purpose

The purpose of modelling in this research was to explore the behaviour and interactions of the stakeholders with the Wear Catchment Partnership involved in the acquisition of data with regards to the management of water resources in the Wear Catchment. Through the modelling of such interactions of stakeholders and the Wear Catchment Partnership in the process of stakeholders acquiring and delivering data to the Wear Catchment Partnership it provided an opportunity to explore partnership working across the catchment, giving an insight into the behaviours of stakeholders relating to their resources. Modelling interactions of stakeholder behaviours in this research built upon knowledge and information derived from the network analysis of the catchment system, and qualitative analysis of interviews with stakeholders. The model in this research focused on the core stakeholders identified in this research, at the centre of the network system, namely, the Wear Rivers Trust, Northumbrian Water, the Environment Agency, and Durham County Council, all of whom are also involved in the Wear Catchment Partnership.

The Wear Catchment Partnership was chosen to base the model in this research as it comprises of the group of stakeholders who are responsible for the implementation of the CaBA in the Wear Catchment. Modelling of the communication and workings of the stakeholders involved in the Partnership based on SNA and thematic analysis of interviews, it was intended that through the modelling of possible scenarios of change such as the decline in resource availability of some stakeholders, that the results of the modelling could be used to inform discussions of the Wear Catchment Partnership on ways of moving forward, understanding the current status of the CaBA in the Catchment, and how the Partnership working may look and operate in the future. For example, in the balancing of the requirements and requests made to stakeholders, in this case in the

acquisition of data to manage water issues in the Wear Catchment through the Wear Catchment Partnership.

Overview – Entities, State Variables and Scales

Agents

The agents in the model are based on the core stakeholders involved in the Wear Catchment Partnership and could be representative of other stakeholder groups working in other catchments across the UK. Each of the agents represents a stakeholder organisation, and not a single individual person. The agents in the model are (note, the abbreviations in courier are how the Wear Catchment Partnership and stakeholder organisations are referred to in NetLogo):

Wear Catchment Partnership, WCP;

Wear Rivers Trust, WRT;

Environment Agency, EA;

Northumbrian Water, NW; and

Durham County Council, DCC

Each of the agents in the model have a number of variables which represent their characteristics and abilities to act. All of the agents have the same characteristics, but are represented at difference strengths, for example, one agent may have more resources than another. The agents' characteristics are:

1. The capacity of the stakeholders to be able to focus their attention (time) and workforce on the acquisition of data.
2. Access to data within their respective organisation required by the Wear Catchment Partnership.
3. The ability of the stakeholder to acquire data from their organisation and deliver it to the Wear Catchment Partnership.

A percentage score of between 10 and 100% is allocated for time and workforce resources for each of the stakeholders, (10% being the minimum to allow for the model to be able to run). Scores are assigned relatively amongst the actors and are not quantitatively representative of any absolute measure. The scores represent the capacity and capability of the stakeholder organisations when involved in the process of data acquisition for the Partnership. The resource scores for time and workforce resources are summed and the

average percentage is input as resources (%) into the model. In the model the resources measure assumes that the characteristics of the agents all directly and equally contribute to the ability of the stakeholder organisation in the data-acquisition process. In the model arbitrary weightings for resources are used and are 25% for time resources and 75% for workforce, giving greater weight to workforce with the assumption that without employees within the organisations to acquire the data it would have a greater impact on meeting the requests of the Wear Catchment Partnership, slowing the response time, and decreasing the amount of data delivered over the three months between meetings.

Environment

The environment in the model represents a non-spatial representation showing the interactions between the stakeholder organisations, involving the communication, transfer and delivery of data by stakeholders to the Wear Catchment Partnership.

Temporal Scales

Each model time-step (tick) represents one hour, and the model runs for 480 hours, which equates to five working days of eight hours per day for 12 weeks (three months). Three months is the average time duration between Wear Catchment Partnership meetings. It is assumed that decisions made by the stakeholders are happening daily, with the interactions happening at a rate based on communication. In the model it is assumed that the stakeholders send their data to the Wear Catchment Partnership via email.

Overview – Process Overview and Scheduling

In the model as stakeholders undertake their strategies regarding the acquisition of data, they produce actions and communicate with one another. In order for agents to undertake these strategies, actions, and to communicate with one another in the model, the model uses BDI and FIPA messaging systems. Using BDI and FIPA, the agents are able to add and execute intentions (commands) in the model throughout their strategies and are also able to pass and respond to messages.

The following details what happens in each of the stages of the modelling process:

Role – Stakeholders decide if they have the ability and sufficient resources to be able to assist with the acquisition of the data required by the Wear Catchment Partnership. The ability of the stakeholders is defined as being able to provide the data themselves. Resources (%) is the parameter in the model that can be varied, encompassing the

organisation's time and workforce, i.e. if they have an individual or a team of individuals who can process the request, and are able to schedule in and accommodate the task along with their current workload.

Communication – In the process of acquiring the data, the stakeholders communicate with the Wear Catchment Partnership, involving the adding and execution of intentions (commands) throughout their strategies, as well as passing and responding to messages. The time taken to communicate can be varied depending on the stakeholder, and in different stages of the model, i.e. in the processing of the data requests and going to their database, delivering data to the Wear Catchment Partnership, and when visiting their HR Department.

Delivery – Delivery of data is to the Wear Catchment Partnership is via email.

Overview – Design Concepts

1. Emergence

The order in which the stakeholders begin to work and interact with the Wear Catchment Partnership, and acquire new resources is emergent by the stakeholder's strategy (Figure 6.3).

2. Adaptation

Behaviour of the agents in the ABM is predominantly based on indirect-objective-seeking, where the choices the stakeholders make are programmed to happen at certain decision-points to reproduce the behaviour representative of the real system, i.e. the real world. Adaptation in the model occurs when the agents react to the requests of other agents and messages, as well as the environment in which they are in, in the case of this research, the environment of the Wear Catchment Partnership. The strategies of the agents in the model do not change.

Design Concepts – Sensing

The Wear Catchment Partnership in the model is able to sense the characteristics of the stakeholder agents in the model, i.e. the Wear Rivers Trust, Northumbrian Water, the Environment Agency and Durham County Council. Sensing in the model symbolises the processes of sharing and exchange of knowledge and resources when stakeholders agree to provide data to the Wear Catchment Partnership and to work together with them.

Design Concepts – Interaction

Agents in the model are only able to interact with the Wear Catchment Partnership. The focus of the process of interaction of the respective stakeholders with the Wear Catchment Partnership in the model is on: (1) the choice of when the stakeholders choose to interact with the Wear Catchment Partnership; and (2) when to respond to requests for data, for example. Interactions in the model are conducted via the process of message passing. Stakeholder agents are able to interact with the Wear Catchment Partnership through sending messages, replies, and further messages to each other in the model, creating links between them, or beginning action.

Details – Initialisation

The initialisation of the model involves the setting of the starting conditions for the stakeholder agents, specifically the scores for workforce and time resources, which are added together to give an overall resources (%) measure for each of the stakeholders. See section 6.13.1 for the initial model conditions.

Agent Learning

In this model the agents have a basic form of memory, which allows them to try new actions if a problem is persisting if they have already attempted previous actions to resolve the problem.

Stakeholder Strategies

In the model each of the stakeholders have their own strategies and processes, detailing the objectives of the agents and incorporating their organisational beliefs. Figures 6.2 and 6.3 show the flowcharts detailing the strategies for the Wear Catchment Partnership and the stakeholders respectively.

6.13. Model Runs

6.13.1. Model Initialisation

The initialisation of the model involves the setting of the stakeholders' resources (%). The initial conditions of the model assume all stakeholders have the maximum time and workforce resources, i.e. 100%. Once the model is set-up, such that the initial input values for resources (%) to be calculated are set, the model can then be set to run. When the stakeholders have delivered all of their respective data, they have available (i.e. 100%)

for the Wear catchment to the Wear Catchment Partnership they stop, implicitly until the next meeting and no further actions in the model are performed by them.

6.13.2. Running of the Model

Figures 6.4 to 6.6 show a series of screen shots taken throughout the running of the model, and relate to the following stages which occur in each run of the model:

1. The respective stakeholders move to their database (represented in the model by one overall database for visual simplicity) to collect the data requested by the Wear Catchment Partnership (Figure 6.4).
2. The stakeholders then deliver their data to the Wear Catchment Partnership (Figure 6.5).
3. The Wear Catchment Partnership looks at the data that have been delivered by the stakeholders, and subsequently requests more data if required (i.e. total data delivered from the respective stakeholder organisations has not reached 100%) (see Figure 6.4).
4. If the stakeholders need to increase their resources to be able to acquire and deliver the data to the Wear Catchment Partnership, they visit their respective Human Resources (HR) departments (represented in the model by one overall HR department for visual simplicity) (Figure 6.6).

Figure 6.4: Stakeholders move to their respective databases (in the direction shown by the arrow) to collect the data that has been requested by the Wear Catchment Partnership.

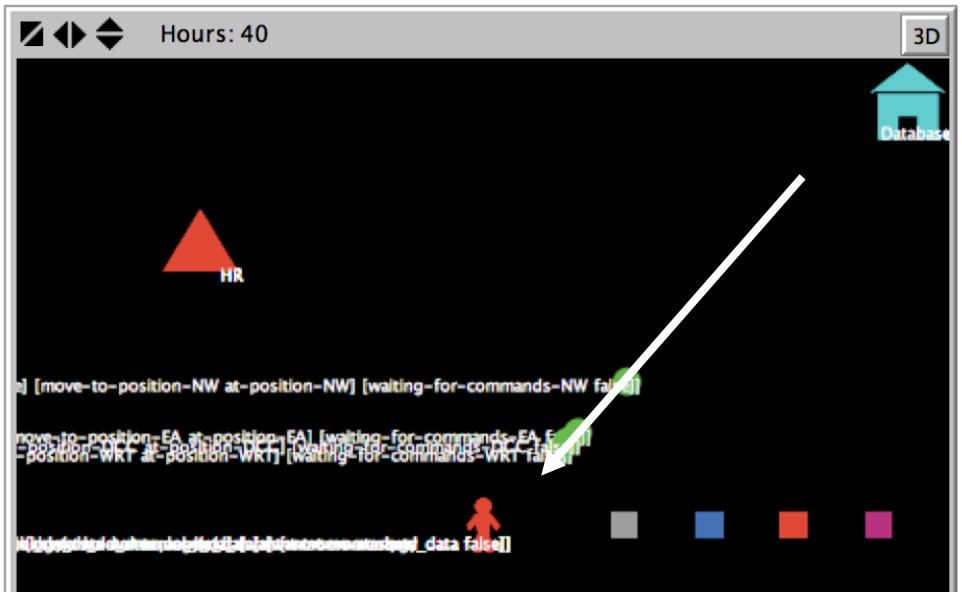

Figure 6.5: Stakeholders deliver the data to the Wear Catchment Partnership (in the direction shown by the arrow).

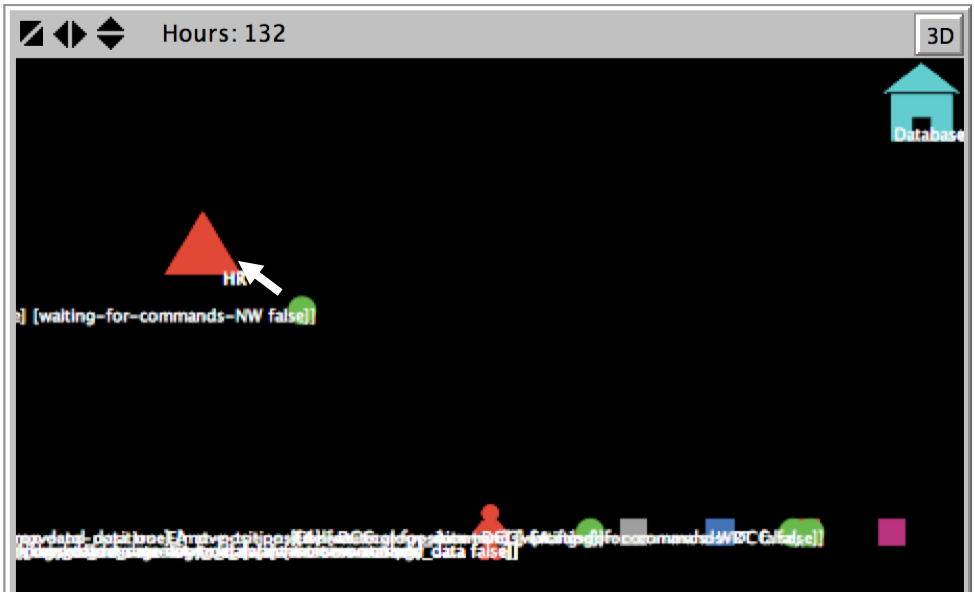

Figure 6.6: Stakeholders visit their HR departments if they need to increase their resources (in this example Northumbrian Water) in the direction shown by the white arrow).

6.13.3. Effect of Varying Resources and Response Times on the Data Delivered to the Wear Catchment Partnership

In ABM, simple experiments can be conducted. Firstly, in this research, the stakeholders' resources, and secondly their response times were varied, to assess and investigate the impact on the amount of data the stakeholders could deliver to the Wear Catchment Partnership (Figure 6.7). The stakeholders still made the same decisions; however, the time taken to make the decisions and follow through their intended actions were faster or slower. For these model runs involving a change in response times, resources both time and workforce remained constant at 100% for all stakeholders.

Figure 6.7a shows the total data delivered (%) by each of the stakeholder organisations to the Wear Catchment Partnership when the stakeholders' time and workforce resources were set to 100%. Overall an average of 32% of data was delivered to the Partnership for the Wear Catchment, with 40%, 34%, 30% and 24% of their data been delivered by Northumbrian Water, the Environment Agency, the Wear Rivers Trust, and Durham County Council respectively. Decreasing the time and workforce resources of all of the stakeholders to 50% had no effect on the total data delivered to the Wear Catchment Partnership. However, decreasing the percentage resources to 25% there was a 1.5% decrease in the average total data delivered to the Partnership. The amount of data delivered by Northumbrian Water from their database remained at 40%, but decreased by 2% for the Environment Agency, the Wear Rivers Trust and Durham County Council. By decreasing all resources to 10%, there was a 4% decrease in the amount of data that was delivered to the Partnership (Figure 6.7b).

The decreasing of the time resource whilst keeping the workforce resource at 100% for all stakeholders had no effect on the model outputs, with the average total data delivered to the Wear Catchment Partnership having remained at 32%. However, decreasing the workforce resource to 10% whilst keeping the time resource at 100% for all stakeholders caused the average total data delivered to the Wear Catchment Partnership to decrease by 0.5% compared to when all resources were at 100%.

By doubling the response time of stakeholders, slowing the speed at which they moved to their databases it resulted in a decrease of 3% in the total average data delivered to the Wear Catchment Partnership by the stakeholders (Figure 6.7c). The amount of data delivered by each of the stakeholders from their databases was 36% for Northumbrian

Water, 30% for the Environment Agency, 26% for the Wear Rivers Trust and 24% for Durham County Council. However, by halving the response time, and thus speeding up the process of the stakeholders moving to their databases resulted in a 3% increase in the total average data delivered to the Wear Catchment Partnership, with the amount of data delivered by Northumbrian Water, the Environment Agency, the Wear Rivers Trust, and Durham County Council from their databases been 44%, 38%, 30% and 28% respectively (Figure 6.7d).

Also, by doubling the time taken by the stakeholders to deliver their acquired data to the Wear Catchment Partnership, it resulted in the total average data delivered to the Partnership to decrease to 23.5% (Figure 6.7e). Under these conditions, the amount of data delivered by Northumbrian Water, the Environment Agency, the Wear Rivers Trust, and Durham County Council from their databases was 30%, 26%, 20% and 18% respectively. However, by halving the time taken for the stakeholders to deliver their data to the Wear Catchment Partnership, the total average data delivered was 39.5%, with Northumbrian Water having delivered 50% of their data, the Environment Agency 42%, the Wear Rivers Trust 36%, and Durham County Council 30% (Figure 6.7f).

By doubling the time taken by the stakeholders to move to their HR Department to acquire additional resources when required, there were no changes in the total data delivered by the stakeholders to the Partnership. This was also the case when the time taken to reach the HR departments was halved.

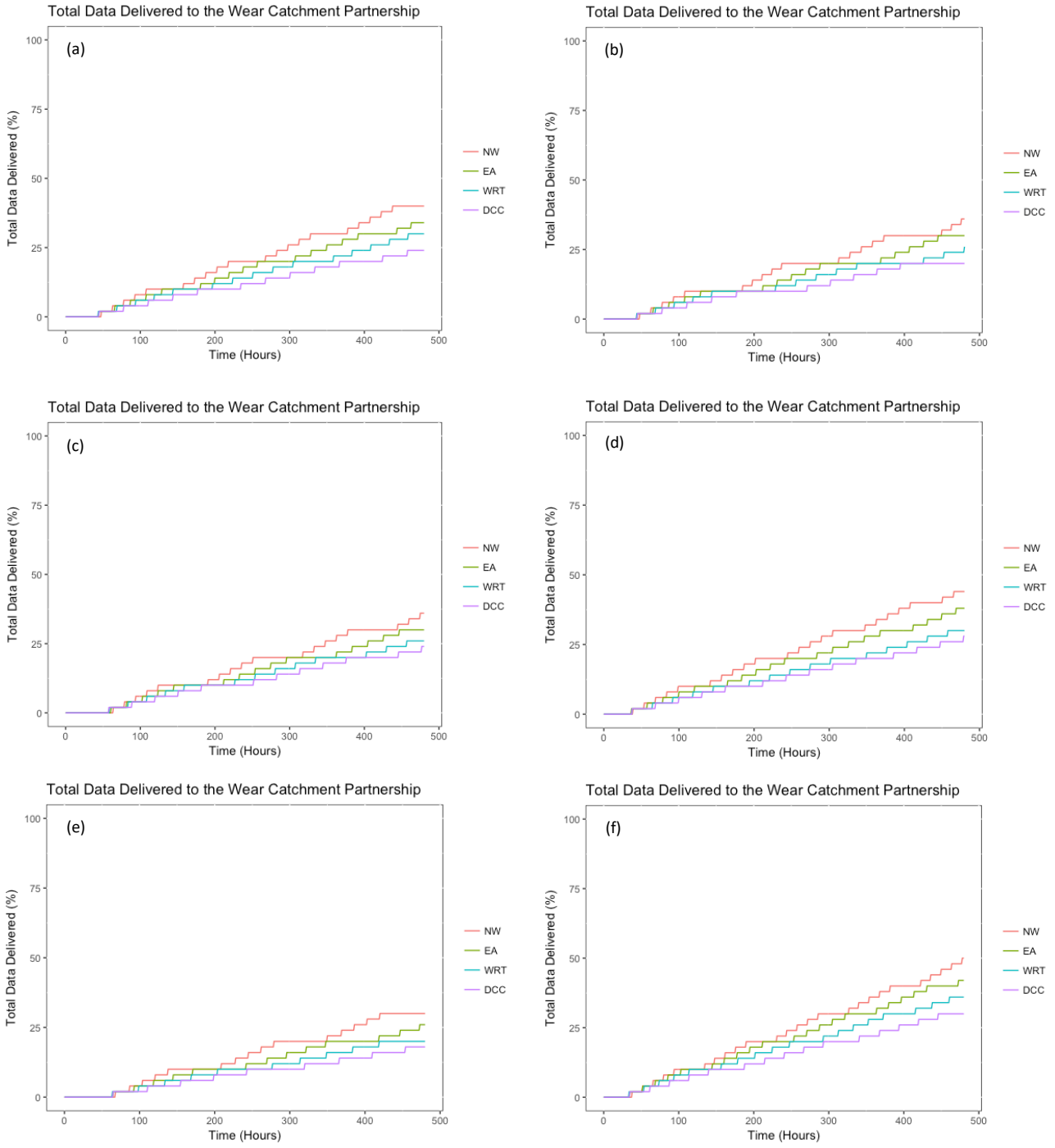

Figure 6.7: Total data delivered (%) by each of the stakeholders to the Wear Catchment Partnership (a) time and workforce resources 100% for all; (b) time and workforce resources 10% for all; (c) doubling of the response time of stakeholders moving to their databases; (d) halving of the response time of stakeholders moving to their databases; (e) doubling of the time taken by the stakeholders to deliver their data to the Partnership; (f) halving of the time taken by the stakeholders to deliver their data to the Partnership.

By combining the optimal resources (%) together with the best-case scenario time delays i.e. the shortest considered in this research, with 100% time and workforce resources, together with the doubling of the speed of all stakeholder responses, over the period of three months between meetings, the average total data delivered to the Partnership was 44.5% (Figure 6.8). The amount of data delivered by the stakeholder organisations from their databases was 60% by Northumbrian Water, 46% by the Environment Agency, 40% by the Wear Rivers Trust and 32% by Durham County Council. Over a period of less 12 months, under these model conditions it would be possible for all of the stakeholder organisations to be able to deliver 100% of their data to the Wear Catchment Partnership.

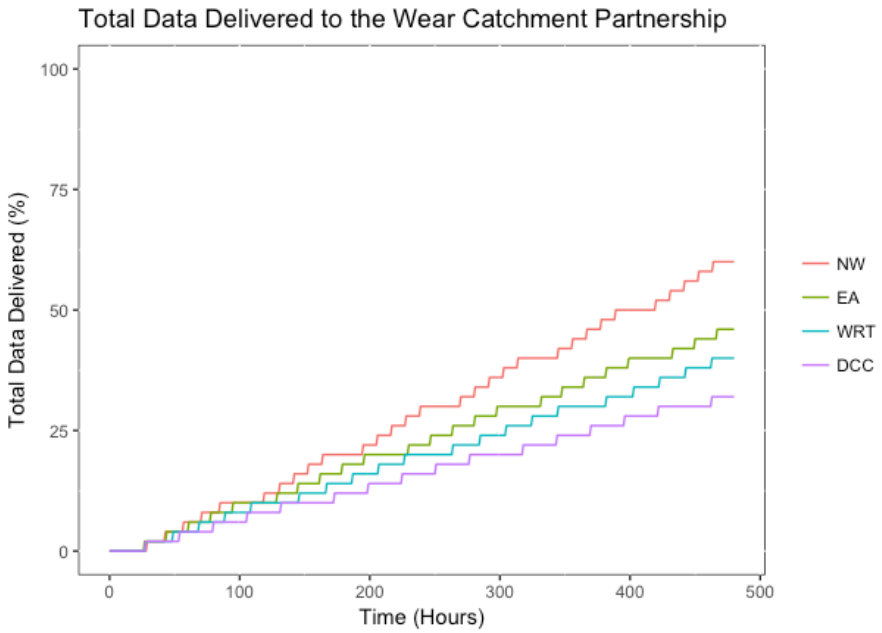

Figure 6.8: Total data delivered (%) by each of the stakeholders to the Wear Catchment Partnership – halving of the time taken by the stakeholders to visit their databases and to deliver their data to the Partnership, with all stakeholders having 100% time and workforce resources.

6.14. Discussion and Interpretation of ABM

Based on the results from the ABM, it is possible to answer the key modelling questions proposed in Section 6.11. To reiterate, the modelling questions focus on how changes made to the stakeholders' resources (time and workforce) and response times may affect the ability to acquire and deliver data to the Wear Catchment Partnership. In the first of the model runs, with maximum resources a total average of 32% of data was delivered to the Partnership by the four stakeholders. Assuming that the stakeholders would be able

to deliver the same amount of data to the Wear Catchment Partnership across a succession of nine months, during which there would be three Partnership meetings, by the start of the fourth meeting of the year, the Partnership would have approximately 96% of all of the data required from the four stakeholders for the Wear Catchment.

In the model, the lower the resources (%), the sooner the stakeholders have to visit their HR Department, i.e. when their resources reach 0% so as to re-increase their resources, so that they are able to move to their database to acquire the data and deliver it to the Wear Catchment Partnership. Ultimately, the higher the resources, the more efficient the stakeholders can be at delivering the data they have to the Wear Catchment Partnership.

Under the initial conditions it was assumed that the stakeholders were able to fit in the acquisition and delivering of data requested by the Partnership into their existing workloads, with the employees tasked with following up the request been able to put 100% of their working hours into completing the task, with 100% efficiency. However, in reality the stakeholders having such time and workforce resources would be unlikely. This is because, as discussed in Chapter 5, stakeholder organisations are involved in several projects, with the need to prioritise their workload, often with stretched resources. Ultimately, the lower the resources of the stakeholders, the less data delivered to the Wear Catchment Partnership between Partnership meetings.

Besides the effects of the stakeholders' resources on the delivery of data to the Wear Catchment Partnership is the possibility of time delays. In the experiments conducted using the ABM, delays in the delivery of data were introduced: (1) for the stakeholders acquiring data from their databases following the request for data from the Partnership; (2) in the delivery of the data to the Partnership; and (3) in the stakeholders being able to increase their resources by visiting their HR Department. The latter of the three delays had no effect on the amount of data delivered to the Wear Catchment Partnership over the modelled duration of three months.

Firstly, the longer the time it takes stakeholders to respond to data requests, i.e. to complete their actions following the Wear Catchment Partnership meeting, it slows down the process of the acquisition; and, therefore less data is delivered to the Partnership before the next meeting. By increasing the response times, it mimics the effect of competing workloads, with some work taking precedence over other work. The delays may symbolise a process of internal checking of evidence through a lack of trust of external data, as well as the weighing up and balancing of priorities or a process of

meetings and discussions internally to decide whether they, the stakeholder organisation is able to provide data because of data protection laws. In reality, such a decrease would have detrimental effects on the ability of the stakeholders and the Partnership group to identify and manage water resources issues across the Catchment, which would ultimately increase financial costs, and risk to the local environment in terms of who may be affected, for example, if a pollution source is not identified.

Secondly, by doubling the time taken in the delivery of data to the Partnership, the average total data delivered decreased by just under 10%. If the speed of delivery was maintained over the duration of several meetings it would over a year for the Partnership to receive all of the data for the Wear Catchment, they require from the four stakeholders. In reality, however, stakeholders may have data but not send it straight away, either forgetting or prioritising other tasks, i.e. not seeing a task through before starting on a new one. Or they may need to actually collect the data and process it.

Also, by increasing the time taken for the stakeholders to deliver the data to the Wear Catchment Partnership it effects the total amount of data the Partnership has before the next meeting, which may affect discussions in the meeting and ideas in being able to move forward and make progress in water-resource management. Thus, having a knock-on effect to achieving the goals of the WFD in the Catchment, for example.

6.15. Implications of the ABM Findings on the CaBA

The purpose of this section is to draw on the analysis of the ABM and the implications of the findings on the CaBA (see Chapter 1). In this research, ABM was used to build upon and add an additional dimension of analysis, to develop further understanding of the potential impacts of changes to stakeholder behaviour on the functioning of the catchment-management network of the Wear. Using the model as a tool, the findings could be used to start discussions between stakeholders in the Partnership, for example where they may be able to adjust their working practices, to increase their capability and capacity in meeting data requirements of the Partnership

Ultimately, the model could be expanded in future work (see Chapter 8) to incorporate additional stakeholders, and other interactions between stakeholders, not just with the Wear Catchment Partnership, for example. The ABM could also be used by the Partnership and the stakeholders themselves. Rather than being solely reliant on the running of the ABM by a researcher, the stakeholders could freely download and use NetLogo

themselves, and use the model, making changes to their own resources and response times, as well as those of others. The model outputs could then be iteratively used to make and model further scenarios of change; and, therefore be used in developing and following the working practices suggested by the CaBA.

6.16. Summary

In this chapter, ABM has allowed for empirical observations to be combined with the data collected on stakeholder interactions in the Wear Catchment to be enhanced, adding an additional level of depth to the findings of the study. Ultimately, ABM has been used as a "computational petri-dish" (Miller and Page, 2007). Through the exploration of potential scenarios of change in the communication and in the ability of the stakeholders to interact with the Wear Catchment Partnership. The results of the ABM exploration offer a bridge to ways in which the findings of this research are applicable to the providing insights into the current state of the water-resource management system of the Wear catchment, with the potential to start stakeholder discussions on where changes could be made in their behaviour and working practices to improve the efficiency of their working and in the implementation of the CaBA. Ultimately, changes to the working practices have the potential to lead to improvements to the water environment, including achieving the goals of policies such as the WFD.

Chapter 7 – Discussion

The purpose of this chapter is to bring together and discuss and synthesise the findings presented in Chapters 4, 5 and 6 of this thesis. The first section of the chapter focuses on understanding the network structure, and the enablers and barriers to functionality, reflecting on catchment-scale water-resource management in the Wear. Greater depth and discussion regarding the network perspective of catchment-management is given, drawing on the benefits of using an SNA approach, and more specifically the characteristics of the network of stakeholders working in water-resource management in the Wear Catchment. Themes discussed in Chapter 5, including power and trust are revisited and expanded upon. The discussion then moves onto ABM reflecting on the innovative approach of using ABM to build upon SNA and the analysis of interviews to further support understanding and to unravel the complexities associated with the management of water resources at the catchment-scale.

In this research, the analysis of the social interactions between the stakeholders allowed for the development of an understanding of the functionality of the system, which together with the empirical analysis of emergent themes from the interviews, allowed for a picture of the current state of management in the Wear Catchment to be formed. This analysis was then expanded upon using ABM, testing possible future scenarios of change in the organisation and structure of the catchment-management system, including changes in stakeholder behaviour and the ability to deliver data to the Wear Catchment Partnership.

7.1. Structure of the Wear Catchment-management Network

Referring to Chapter 4, this research aimed to provide a conceptualisation of the current network structural relationships between stakeholders working in water-resource management in the Wear Catchment. The first stage of the analysis therefore involved the utilisation of a network approach, specifically SNA, to identify the characteristics of the water-resource management system in the Wear Catchment. SNA was used so as to explore the social dimensions of the system, with the intentions of being able to better understand the current working practices in operation within the catchment, shaped by the CaBA. Ultimately, the network provided a basis for breaking down and challenging the

complexities involved in the management of water resources, with often competing interests, priorities and ideas (Bellamy *et al.*, 2002; Kerr, 2007; Röling and Watson, 2007).

Network analysis is a valuable tool for making catchment-management systems more visible, making it possible to analyse the positions, contexts and interactions of the stakeholders in the system, and to gain an understanding of the collective network underpinning catchment-scale governance of water resources (Stein *et al.*, 2011). Through the use of a network analysis approach in this research, the characterisation of the practice of catchment-management and operationalisation of catchment governance in the Wear was possible, providing key insights into the ways of working of the stakeholders involved. It was possible to identify the characteristics of the system, for example who the key stakeholders are, and to understand the ties between the stakeholders, more specifically the interactions between the stakeholders, and what roles they play in the management of water resources, for example, in the acquisition of data, involvement in problem-solving, political support, and in decision-making processes.

At the centre of the network of stakeholders in the Wear Catchment is the Wear Rivers Trust (Figure 4.2, Chapter 4), holding the majority of ties with other stakeholder organisations. The fact that the Trust is at the centre of the network supports the notion that decision-making is somewhat horizontal, with the decisions regarding the management of water resources not being reliant on decision-making from the top, i.e. the government-level, and instead are largely reliant on the actions of the charity organisation, and the links it holds with other stakeholders. The Trust has a pivotal role in providing problem-solving interactions, political support and data and/or information sharing with others. Despite being a charitable organisation, a number of stakeholders rely on the organisation for their assistance in the management of water resources, giving back what they receive, and reciprocating the relationships they hold with the Wear Rivers Trust.

The analysis of the management system as a network has also provided insights into the likely sustainability of the CaBA, through the interactions of the stakeholders and how these interactions compare to the current governance approach of managing water resources in the UK. The analysis of the network indicated acceptance of the intentions of the CaBA, and the subsequent Wear Catchment Partnership as a system of decision-making involving stakeholders from all levels, not just those responsible at the top driving the requirements of meeting the goals of the WFD. The mapping of the network indicated

a variety of stakeholders from all levels, comprising a mix of public, private and voluntary sector organisations; therefore, supporting the ideas encompassed by the movement away from traditional top-down management approaches, towards being more integrated and bottom-up.

7.2. Breaking Down Network Complexity

Referring back to Chapter 1, water-resource management is complex and uncertain (Chaffin *et al.*, 2016), crossing both biophysical and administrative boundaries, involving many actors. When combined with uncertainty of social and ecological influences, which often play out in unpredictable, random ways (Vörösmarty *et al.*, 2000), the problems of water-resource management are labelled as 'wicked' problems, which themselves are complex and uncertain. Although not addressing these so-called wicked problems directly, the analysis of the network provides one such tool that can be used in the understanding of whether there is sufficient input from stakeholders, and how effectively the management system is organised, as well as answering questions such as, is anyone missing from the network? One of the key outcomes of the network analysis was the ability to build and develop an understanding and knowledge of the system components and their configuration, and specifically in how the stakeholders come together.

The utilisation of a network approach in this research has allowed for a better understanding of the roles and positions of the stakeholders within the management system, as well as the likely influence the stakeholders have on changing practices. The network approach has also provided an indication of where importance is placed in the system, beginning to reveal something of power, for which the wider drivers can be investigated. Referring to the four most central actors of the network, the Wear Rivers Trust, the Environment Agency, Northumbrian Water and Durham County Council, it can be argued that the centrality of the stakeholders is related somewhat to the power vested in the network (Newig *et al.*, 2010). Without their strong connections to the organisations, including the Environment Agency, Northumbrian Water and Durham County Council, the Wear Rivers Trust would be somewhat less connected. As a charitable organisation the Wear Rivers Trust is reliant on funding from others, and without this funding they simply would not be able to operate at the scale at which they do in the catchment. To receive funding from the Environment Agency and Northumbrian Water, for example, the Wear Rivers Trust according to the interviews with employees, prioritise their workload,

putting the needs and requests of the 'more powerful' first. Although the management system appears to be inclusive overall, there is very much an element of hierarchy still present amongst the stakeholders.

The evidence of possible hierarchy in the system leads to suggest that the CaBA is negatively affected by power imbalances based on the centralised influence of the state in the catchment partnerships (Watson, 2014). The central role of the Environment Agency can be attributed to the regulatory function and cross-cutting interactions of the organisation with a wide-range of stakeholders. The Environment Agency played a pivotal role in the setting up of the CaBA, and in the Wear Catchment was originally involved in the joint leadership of the approach. The Wear Rivers Trust, now the sole-lead organisation in the Wear Catchment Partnership, acts as both a facilitator and implementor of the on-the-ground action with regards to the management of water resources in the catchment. The Trust are involved in the strategic planning, joint-working and grant applications for the partnership, representing both a point of strength and weakness in the partnership, as they have the ability of being able to bring groups together, and without them the network would ultimately be weakened, as demonstrated in Chapter 4. They are one of the organisations, who, if removed, would result in a breakdown in the connectedness of organisations in the network. Without the Wear Rivers Trust, significant contacts and linkages would be lost from the network, in particular to stakeholders on the peripheries of the network including community groups, who go to the Trust with knowledge of pollution sources they have spotted along the course of rivers, for example. Without this knowledge of water issues, it could potentially take longer for the issues to be addressed. There would be a lack of contact between the public and organisations such as the Environment Agency who can tackle the issues identified.

The resilience of networks is an important consideration to be made. In complex systems, such as the catchment-management system, the capacity of the system to cope with adaptation is dependent upon the structure of the network, and the ability of the stakeholders to react to changes, both environmental and social changes. Examples of environmental changes could be changes to the quality of water as a result of pollution incidents, be they short- or long-term; and social changes, such as changes to the individuals employed in an organisation, or population change in the catchment resulting in potentially more people at risk of flooding, for example.

One indication of the ability of the network to react and adapt to changes in the network is the volume and diversity of ties in the network. As discussed by Granovetter (1973), one way of understanding the configuration of the network is by looking at the strength of the network ties, and the effects that different tie strengths have based on factors such as trust, closeness, and frequency of the exchange between stakeholders, which can ultimately affect the functionality of the network.

Referring to the strength of ties in the Wear Catchment network, there is a mix of both strong and weak ties (see Figure 4.4, Chapter 4). According to Granovetter (1973) the strength of weak ties in the network matters in leveraging advantage within the network rather than stronger, closer ties. Strong ties are indicative of the ability of stakeholders to influence one another, as well as, share views, offer support, communicate effectively, and to develop and maintain a trusting working relationship (Prell *et al.*, 2009). However, strong ties typically exist between stakeholders of similar nature, which when referring to resilience against change may be problematic with stakeholders who have a similar style of working and thinking, and therefore may be unable to successfully adapt to change. Having weak ties alongside strong ties, however, are often between more diverse groups (Prell *et al.*, 2009; Newig *et al.*, 2010). Therefore, beneficial in addressing and dealing with the challenges of complexity in the management system. With a mix of strong and weak ties, it could be argued that the catchment-management in the system is relatively more resilient to change, than if it were made up of a majority strong ties between stakeholders.

Ultimately, having a diverse network of stakeholders is beneficial. The more diversity the more opportunity the stakeholders have to be part of multiple modes and aspects of water-resource management, and therefore, more likely to have greater access to knowledge and expertise that they would not otherwise have. The sharing of knowledge and expertise is particularly important, with stakeholders respecting the views and opinions of one another it is likely to contribute towards enhancing the connectedness of the network. Feeling connected is important in the network as it is likely to enhance future collaborative working between stakeholders, which will be of benefit to environmental management. By having an awareness of which links are missing, for example, between the Wear Rivers Trust and Sunderland City Council in the Wear Catchment, there is potential for the future growth and development of the network, to work towards shared goals in the future with regards to the management of water resources.

7.3. Potential Limitations of the Network Approach

However, it is also important to remain aware of the limitations and difficulties associated with the use of a network approach to analyse the social dimensions of a catchment system. The sociograms produced in SNA are only a snapshot in time, and therefore need to be analysed and interpreted carefully, as one representation of the network. Depending on who is asked to participate, or indeed participates in the acquisition of data on the network it determines what the network looks like. Instead, the network representing a catchment-system should be used as a guide, highlighting points of interest and concern in the complexity of managing water resources, indicating who is and who is not involved. SNA offers some but not all of the information required in understanding the complexity of the management system. The further analysis of the social network in this research using information gleaned from interviews, made it possible to develop and enhance understanding of the links between the stakeholders, gaining insight into how they communicate, support and work together. Through the bringing together of the thematic analysis of interviews to supplement the analysis of the network, it allowed for a greater insight and understanding of the purposes and strength of ties between the stakeholders. It also revealed evidence of enablers and barriers to the functioning of catchment-management. In the context of the CaBA, it is important to be aware of such factors, which have the potential to affect the future sustainability and strength of the approach.

7.4. Enablers and Barriers to the Functionality of the Network

Within the network it is apparent from the analysis of the interviews that communication between stakeholders is crucial (Bendell, 2000; Crane and Livesey, 2003; Foster and Jonker, 2005; Jackson, 2007). Without effective communication, the ability of stakeholders being able to engage with others would be detrimentally affected (Welch and Jackson, 2007). Communication is essential for stakeholders to be aware of what others are doing, what information or support they need from each other, and deciding in how best to move forwards with regards to the management of water resources in the future. As detailed in Chapter 5 without awareness of others and their current state and progress of work in the catchment, there would be potential for mismatch in ideas for future management, creating potential for an inconsistent implementation of the CaBA.

Another key factor which affects the functionality of the management system is the presence of trust between the stakeholders. With a lack of trust, it can result in the loss and potential exclusion of otherwise useful stakeholder expertise and knowledge. The lack of trust can result in illegitimacy. As detailed by Sandström *et al.* (2014), legitimacy can be thought about as one of the outcomes of collaboration, and considers co-management as a facilitator of deliberation and articulation of the bringing together of different interests, developing understandings, common agreements, and, finally the acceptance of the parties involved. However, in reality the development of legitimacy in catchment-management between stakeholders is complex, depending on the behaviours and attitudes of the stakeholders involved and their willingness to be open to change. In the Wear Catchment one example of the legitimacy challenges is the acceptance of community groups in the management of water resources. Despite being a valued source of knowledge and expertise by the Wear Rivers Trust, community groups yet remain to play any significant role in the actual Wear Catchment Partnership meetings. In comparison to the Environment Agency, Northumbrian Water and Durham County Council, for example, the community have essentially no or little voice in the decision-making processes, despite being sources of information, and the people who are indeed likely to be most affected by the management decisions made by the other stakeholder groups.

At the individual level, there are also factors that can enable or negatively affect action and interaction between stakeholder organisations. In the Wear Catchment some individuals interviewed expressed concern about the adequacy of their knowledge and expertise relative to what they deemed to be more-experienced individuals within their own and other organisations with whom they work. Individuals in this position who essentially 'downplay' their experience relative to others may hold back their thoughts and ideas, meaning they contribute less than they could or indeed should. Equally, there are individuals who are strong and dominant characters, who are active in problem-solving, expressing their ideas and are keen for implementing action using their knowledge and expertise. However, finding a balance between individuals is somewhat difficult, but nonetheless the important thing to consider in catchment-management is ensuring that all voices are being heard, something which in the Wear Catchment is yet to be achieved.

Another potential barrier in catchment-management is continuity of workforce. Typical of many organisations, individuals tend to move around, moving from job to job, and organisation to organisation, rather than remaining settled in one post. If individuals do remain in the same organisation, some strive to move up the ladder, gaining more responsibilities, and therefore the need to prioritise and potentially drop existing projects in favour of new ones. In the Wear Catchment there has been high turnover of the Environment Agency Wear Catchment Coordinator. As discussed in Chapter 5, the loss and subsequent replacement of individuals means the loss of contacts, knowledge and expertise. On the one hand the replacement may bring with them fresh ideas, but on the other they need to be brought up to speed with the project and develop a rapport with the existing individuals involved in the catchment-management. They could also slow down and even affect the workflow, and therefore negatively affect advances made to the management of water issues in the catchment, thus acting as a barrier to progress. Inevitably all involved in catchment-management have their own ideas and agendas, from individuals through to the stakeholder organisations as a whole, which indeed adds another layer of complexity on top of the existing complexities associated with the management of water resources.

7.5. Insights from the Innovative Approach of Bringing together SNA, the Analysis of Interviews and ABM

Through the use of ABM involving the modelling of stakeholder actions and interactions in the acquisition of data in the context of the Wear Catchment Partnership, it has helped in the unravelling of some of the complexities surrounding water-resource management. By starting with an understanding from SNA and the thematic analysis of interviews, the process of modelling has highlighted how the behaviour of stakeholders varies depending on their resources, specifically, time and workforce resources, and how adjusting them can affect the outputs of the modelling process. The ABM also investigated and demonstrated the potential impact of adding delays in the response times of stakeholders acquiring and delivering their data, and the effects on the amount of data that the stakeholders delivered to the Wear Catchment Partnership before the next meeting (see Chapter 6). Ultimately, the modelling process supported and enhanced the investigation and analysis of the current working practices of the stakeholders, and how possible future scenarios of change could affect the efficiency and outcomes of working with regards to

the acquisition of data, which can subsequently be used in the addressing and developing management of water resources.

In the ABM created in this research it is that with decreasing resources the ability of the stakeholders to deliver data to the Wear Catchment Partnership is reduced (Chapter 6). Time which could otherwise be spent by the stakeholders on the acquisition of data is instead used in visiting their HR departments to increase their resources. The modelling therefore highlights the importance of stakeholders being open about their abilities, competing workloads and capacities to complete tasks when they are decided upon and allocated at meetings. Without the Wear Catchment Partnership, in the case of this research, or indeed other stakeholder organisations being aware of the capability and capacity of others, it could lead have a negative effect on the achievement of water-resource management goals, and indeed deters the collaborative nature of the CaBA.

Through the incorporation of time delays in the meeting and delivery of requests for data in the ABM it built upon the points made by interviewees (Chapter 5) regarding the responsiveness of stakeholders to data requests. In the interviews it was apparent that the delays can lead to frustration, and the need to acquire data from elsewhere, along with a knock-on having subsequent decreases in data for other partnership and project group meetings affecting the meeting of deadlines. In the model, it was demonstrated that increasing time delays decreased the total data delivered to the Partnership, which could in reality have an effect on future working relations, resulting in a decrease in the strength of ties between existing working partners, and thus having a negative effect on collaborative working across the network.

7.6. Stakeholder Working at the Catchment-Scale and the Future of the CaBA

Ultimately, it is important to understand what influences or encourages stakeholders to want to work together. In this research, several factors have been found to be influential in the involvement of stakeholders in water-resource management, and these include, enablers and barriers, norms and expectations, policy goals (such as the WFD), power dynamics, socio-political context, historical context, and the problems and issues associated with water resources in the catchment. Understanding of these factors together can be used to breakdown the complexities of the catchment-management system further. By understanding the relations between elements, which in the case of

this research is the stakeholders involved in water-resource management. At the catchment-scale, complexity is a familiar concept, referring to the various and often competing stakeholders involved in decision-making processes, along with the uncertainty and interactions between the many different environments, social systems and areas of action, such as different water-resource management groups, that branch off from the Wear Catchment Partnership, for example (Bellamy *et al.*, 2002; Hirsch, 2006; Ison *et al.*, 2007; Patterson, 2016).

The move away from the traditional top-down approaches in water-resource management, towards more collaborative, catchment-wide approaches, involving a wide-range of stakeholders is starting to embrace and recognise the need to break-down and challenge complexity in catchment-management processes (Pahl-Wostl *et al.*, 2012). Focusing on one aspect of the catchment, or indeed on the perspective of a restricted group of stakeholders, is no longer an option. In order for the successful management of water resources, achieving the goals of policies such as the WFD, there needs to be an all-encompassing approach to water-resource management, as the CaBA is striving to achieve at the catchment-scale in the UK.

Within the network the existence of ties between stakeholders are not always positive, and instead the connections are complicated through poor working relations, trust, and disagreements between the stakeholders involved. When combined with knowledge from the interviews, it became apparent in the context of the Wear Catchment that some relations, despite having started out as positive, have unfortunately deteriorated overtime. In some instances, the deterioration of once positive working relations has been as a result of staff leaving the organisation, competing workloads, and ultimately a lack of resources, including time, money and workforce. Examples in the network of the Wear Catchment include the high turnover of the Environment Agency's Catchment Coordinator, and the lack of involvement of Sunderland City Council in water-resource management within the Wear Catchment Partnership due to a lack of time and persons to become involved, which is ultimately connected to the broader issues of austerity and local government cuts.

The Wear Catchment Partnership has the potential to address and overcome the lack of connection between stakeholders, pulling together stakeholder knowledge and expertise, and therefore, showing the worth and requirement of stakeholders from all levels in the Catchment. By pulling together the priorities of the stakeholders, allowing them to bring

together their knowledge and understanding, the Partnership is key to facilitating action amongst the stakeholders, bringing them together in meetings, and putting them around the same table, enabling face-to-face interactions and thus, decision-making. Integrated learning from one another, using the strengths of the stakeholders to inform decision-making is key to developing trust between the stakeholders, making their worth visible in catchment-management to one another.

It is inevitable, however, that the desires of all stakeholders will be determined by the institutional beliefs of their organisations, such as, the priorities for management, which in the case of the Wear Rivers Trust is the restoration of the river environment through close working with the local community, whilst Northumbrian Water as a business is the provision of drinking water and the treatment of waste-water, etc. Recognising these differences in organisational goals and priorities is important. Organisations also have their own, and often competing social and political power dynamics. Taking into consideration the needs, desires and dynamics of the stakeholder organisations is essential to ensure collaborative working, towards the goals of catchment-management under the CaBA. Ultimately, complexity affects the functionality of the management of systems. By using the findings of this research in the network of the catchment-management system, together with details on the interactions between the stakeholders, and their roles in water-resource management, it contributes towards the identification of the next stages of the CaBA, and how stakeholders could work together in the future, and also work with others not currently involved to overcome the barriers and difficulties in catchment-management as a whole.

As observed in a number of organisations, there are problems associated with the poor incorporation of individuals from a range of diverse backgrounds, be that ethnicity, gender or disability. This is something yet to be challenged and addressed by the CaBA, with focus being dominantly on the inclusion of stakeholders from all levels, but with little or no recognition of the individuals working within them. Diversity amongst individuals from a range of backgrounds is important in the generation of a range of opinions, perspectives and areas of expertise. Ultimately, the next stage of success of partnership working is dependent on the input of individuals, and if all representatives are similar in terms of their personal characteristics, including their ethnicity and abilities it immediately limits the potential for the generation of a greater set of opinions and perspectives.

Not only is it important to have inclusivity of a range of individuals within the stakeholder organisations, it is also important to remain aware that all organisations, and the individuals within them have their own opinions. No two people, or organisations, have exactly the same opinion. It is, therefore, important that individuals and organisations are aware of the differences in opinions and are able to be respectful in remaining open-minded regarding the perspectives of others. All perspectives are valid, and all of the perspectives need to be represented and visible to all within the network of stakeholders. Referring back to the network of stakeholder organisations working in the Wear Catchment, despite the Wear Rivers Trust, Environment Agency, Northumbrian Water, and Durham County Council being at the centre of the network, it does not necessarily mean they have a broad or complete view of all of the perspectives of others in the network; and is an area that needs to be addressed with reference to the implementation of the CaBA in the Wear Catchment.

Another challenge moving into the future of the CaBA is ensuring the continued progress of the implementation of the approach. In order to ensure continued working of the Wear Catchment Partnership, it is essential to maintain the power of the Partnership in addressing and managing water issues at the catchment-scale. This is by continuing to work towards and achieving the balance between horizontal engagements across water-resource management, with a vertical balance between the involvements of stakeholders from all levels.

7.7. Researcher Reflections

At a personal level as a researcher, an additional level of complexity in the research process was the positioning of myself, in a professional capacity working with stakeholders from across the Wear Catchment. Through regular contact with members of stakeholder organisations through attendance at Wear Catchment Partnership, Heritage Coast, the Greening the Twizell, and Topsoil meetings during and prior to data collection, it was possible to gain some knowledge of the interactions and involvement of the stakeholders in water-resource management in the Wear Catchment. The building up of good rapport was useful in the distribution and circulation of the survey in this research used to collect data on the network of stakeholders in the Catchment.

Without these connections and personal contacts, it is inevitable that data collection would have been somewhat more difficult and time-consuming. It is also likely that

uptake in survey and interview participation could have been lower. As an unknown PhD researcher to the stakeholder organisations, people may have been less willing to participate in the research than if they were asked by a well-known and active employee of one of the stakeholder organisations at the centre of the network, for example.

7.8. Summary

From the investigations into the current status of water-resource management in the Wear Catchment with respect to the CaBA, the findings can be drawn out and offer some insight and assessment into the status of catchment-management in the UK as a whole. For example, what is working with the CaBA approach, and where do the strengths and weaknesses of the current approach to water-resource management in the Wear catchment lie?

Chapter 7 has presented the discussion and interpretations of the findings of Chapters 4, 5 and 6 of this thesis, summarising the core themes, evaluating and explaining them. Focus has been given to the understanding of the network structure and functionality in the context of the Wear Catchment, highlighting the importance of being able to visualise the network of the system, providing a baseline understanding of the catchment-system in the context of the CaBA. The enablers and barriers to the functioning of water-resource management in the Wear Catchment have been discussed, along with exploration of the complexities associated with catchment-management processes. Specific in-depth focus was given to working through and discussing the complexities associated with water-resource management at the catchment-scale, drawing on the competing interests of stakeholders, the modelling of stakeholder behaviour and interactions with the Wear Catchment Partnership, future challenges of the CaBA, and researcher positionality in conducting this research.

Chapter 8 – Conclusions

This chapter concludes the thesis, drawing on the overall findings of the research, offering final reflections of the research and the research process. Reference is made back to the overall aim and research objectives as detailed in Chapter 1. Analysis of the potential wider implications of the research findings is given in the context of water-resource management in the Wear and beyond the scope of the Wear Catchment with reference to the current status of water-resource management in the UK. Finally, recommendations in-light of the research process are stated, along with recommendations of areas of future research.

8.1. Summary of the Research Premise

The motivation of this research was to investigate the current status of water-resource management in the UK, specifically focusing on the interactions of stakeholders, on their working relationships, and their respective roles in the management of water resources. Referring to the desire of Pahl-Wostl (2002), this research offers insights into the use of an innovative approach combining SNA and ABM, to develop knowledge and understanding of the social dimensions of the stakeholders involved in the management process. By developing an understanding of the interactions of stakeholders, we can break down part of the complexity and 'messiness' involved in water-resource management. Understanding of who does what lends itself to improvements that can be made in catchment-management: identifying who is missing from the network; where ties between stakeholder organisations are missing, etc.; and therefore, has led to the analysis of the state of the CaBA in the UK, reflecting on the complexities of enablers and barriers to progress in the governance of water resources. In doing so this research has contributed to the understanding of the current status of water-resource management in the UK, and in recommending potential future directions of the implementation of the CaBA.

The aim of this research was to analyse the current state of water-resource management in the UK, investigating the complexities of water governance arrangements, in particular the social dimension, using the Wear Catchment as a case study. To answer this aim, the following research objectives were proposed:

1. To identify stakeholders involved in water-resource management in the Wear Catchment;
2. To undertake a mixed-methods approach comprising qualitative and quantitative data collection to identify the network of stakeholders working in the Wear Catchment, and their roles within the network;
3. To employ the method of SNA to analyse the stakeholder network, identifying for example, key stakeholders in the network, connections present between stakeholders, and any stakeholders who are part of the network yet remain on the peripheries;
4. To use ABM to explore the possible outcomes of changes made to the stakeholder network, feeding in qualitative and quantitative data collected, using the stakeholder network identified, and to analyse and evaluate the current state of water-resource management in the Wear Catchment relative to possible future scenarios; and
5. To feed through the findings from the research to help inform the wider picture of water-resource management both with specific reference to the Wear Catchment, and beyond to the regional and national levels of the UK.

The objectives were approached in turn, each building up from the previous one. Objective 1 involved in the identification of stakeholder organisations involved in water-resource management in the Wear Catchment. The organisations identified were asked to participate in the data collection of this research (Objective 2), initially being sent the survey, and secondly asked if they were willing partake in interviews following-up and discussing their survey responses in greater detail. A snowballing approach to the recruitment of participants was employed, making use of contacts of those who had completed the survey. Using the survey responses, Objective 3, involved the analysis of the data using SNA, visualising the network of stakeholders, and investigating the purpose and strength of ties between them. Stakeholders at the centre of the network were identified, along with those on the peripheries of the network. Further analysis and understanding of the roles of stakeholders in the catchment-management network of the Wear Catchment was achieved through the thematic analysis of interviews conducted with stakeholders. Using the qualitative and quantitative data collected, and the subsequent analysis, ABM was used to further investigate the structure and functionality of the network of stakeholders working in the Wear Catchment (Objective 4). The focus

of the modelling was on the effect of organisations' resources (workforce and time), and the time duration of their responses in the delivery of data to the Wear Catchment Partnership, allowing for the evaluation of potential future scenarios of change were the stakeholders to behave in such a manner. The final objective, Objective 5, involved the bringing together of the findings of this research to evaluate the current status of water-resource management in the Wear Catchment with reference to the CaBA, and how these could be applied to other catchments in the UK.

8.2. Summary of the Key Findings of the Research

Each of the stages of data collection and analysis in this research has contributed towards the improving of understanding of the current state of water-resource management in the UK, using the Wear Catchment as a case study. Understandings of status of UK water-resource management, with specific reference to the progress of the CaBA, using an innovative approach combining SNA and ABM to investigate the social dimensions of managing water resources at the catchment-scale. This research has focused on the social dimensions of water-resource management, i.e. how well the stakeholders do (or do not) work together, the roles they play, and the interactions between them; which, in this research was achieved through exploration of the network of stakeholders involved in the catchment-management system of the Wear Catchment. Findings of the research are summarised under the following headings: (1) structure of the network system for water-resource management in the Wear Catchment, with reference to the CaBA; (2) roles and interactions of the stakeholder organisations in the Wear Catchment-management network; and (3) future changes to the structure of the Wear Catchment-management network.

8.2.1. Structure of the Network System for Water-Resource Management in the Wear Catchment, with Reference to the CaBA

Through the conceptualisation of the relationships between stakeholders involved, and their relative positions within the network, it provided the basis of this research in the investigation of the current status of water-resource management in the Wear Catchment. In doing so, the mapping of the network of stakeholders offered one possible understanding of the construction of the system of stakeholders working in the Wear

Catchment, and on which to base an assessment and investigation of the current state of the CaBA. Within the network, links represent social relations between the stakeholders, comprising of knowledge exchanges, and flows of information or resources between nodes.

Within the Wear Catchment, there is evidence to suggest good working relations between many stakeholders, collaboratively working to manage water resources, including the sharing of data and/or information, and interactions in decision-making, problem-solving and political support. Despite inclusion of a variety of stakeholders from the public, private and voluntary sectors, there is little evidence from the analysis of the network of the involvement of community groups, even though one of the intentions of the CaBA is to provide a means of allowing for community-led approaches, with the intentions of delivering improvements to the water environment.

8.2.2. Roles and Interactions of the Stakeholder Organisations in the Water Catchment-Management Network

Through the analysis of interviews with stakeholders, there is evidence that rather than working individually, the stakeholders make use of the strengths of one another, making use of contacts, knowledge and expertise, and in the sharing of ideas. A number of interviewees expressed and talked about collaborations their organisation has with a wide range of stakeholders in decision-making processes, keeping one another informed, identifying issues and potential outcomes and actions on how best to manage the water environment together.

Even though the Wear Rivers Trust is keen to engage with locals, making use of its knowledge and expertise, there is little sign of the involvement of the community, with a lack of representation at the Wear Catchment Partnership meetings, for example. The only evidence of the involvement of the community is through the use of local knowledge and expertise by the Wear Rivers Trust, as discussed and highlighted Chapter 5.

8.2.3. Future Changes to the Structure of the Wear Catchment-Management Network

ABM allowed for an additional level in the analysis of the interactions inherent in the Wear Catchment network to be explored, specifically those between the Wear Catchment Partnership as a whole, and the Wear Rivers Trust, Northumbrian Water, the

Environment Agency and Durham County Council. By making changes to and assessing the effects of varying the resources of stakeholders, along with delays in timing of stakeholder responses to requests made in practice by the Wear Catchment Partnership, it allowed for results to be generated from the model that could be used to inform future discussions of changes that could be made to the behaviour of stakeholders in the network. Changes that could be made would be increasing their capacity and capability to provide data to the Partnership, and also the sharing of responsibilities between other stakeholders to increase stakeholder resources. More specifically, based on the interactions between stakeholders that have been identified in this research, and the subsequent modelling, stakeholders working in the Wear Catchment could aim to make changes to their working practices, so as to work more effectively, meeting the demands of, for example, data requests.

8.3. Contributions to Water-Resource Management Research

Drawing on the wider contributions of research to the wider field of investigation is an important part of any research. In this section, the contribution to water-resource management research, with reference to the findings from this research are presented. Contributions to existing research from this PhD are separated into two sub-headings, (1) conceptual; and (2) methodological contributions to water-resource management research.

8.3.1. Conceptual Contributions to Water-Resource Management Research

Through the mapping out of stakeholders involved in water-resource management in the Wear Catchment using a network systems approach, this research has contributed to the breaking-down and furthering of the understandings of the complexities involved and intertwined in the management of water resources at the catchment-scale. Specific complexities that have been addressed in this research include the competing interests of stakeholders involved in catchment-management; the modelling of stakeholder interactions in catchment-management; potential future challenges associated with the CaBA; and positionality as a researcher in working with stakeholders.

Analysis of the relationships between stakeholder organisations has revealed insights into the distributions of power and trust in the network. Several factors have been found

in this research to be influential in the stakeholders' relationships, including, enablers and barriers, norms and expectations, policy goals such as the WFD, power dynamics, the socio-political context, historical context, and problems and issues associated with water resources and water-resource management. Through the understanding of these factors, offers potential for the breakdown of complexities of the management-system, offering ways forward, which in the context of this research is with reference to the CaBA.

With reference to the move away from the traditional top-down approach to water-resource management in the UK, a significant contribution of this research is an update of the current state of the CaBA approach. Using the Wear Catchment as a case study, which has been one of the catchments included in the CaBA since the implementation of the pilots in 2011, it has shown that progress has been made. The Wear Catchment Partnership has brought together a number of stakeholders, who indeed are working well together, sharing data and/or information, as well as problem-solving together, offering political support to one another, and assisting each other in decision-making processes. Regular contact and two-way relationships are what strengthen the ties between stakeholders. However, there is still scope for greater inclusion of local communities, with few stakeholders making use of them. With the exception of the Wear Rivers Trust, linking local communities to other stakeholder organisations, using the knowledge of locals to inform for example, the Environment Agency of pollution incidents along rivers, local communities remain largely under-involved in the process of catchment-management.

Although stakeholder organisations may be working together it does not necessarily mean that all relationships are positive. In the Wear Catchment social network, a number of stakeholders could have improved relations with others, sustained over the long-term rather than one-off, one-way communication. A lack of regular or continued interaction, which benefits both, or indeed all parties involved, is problematic in terms of stakeholders gaining and maintaining trust with one another.

Ultimately, there remains quite a significant level of progress that can still be made with the CaBA, not only in terms of diversifying the range of stakeholders involved to include community groups, but also the individuals within those groups. Without diversification of individuals representing the groups, for example, in the Wear Catchment Partnership, it is inevitable that otherwise valuable ideas, knowledge and expertise will be lost, and go to waste.

8.3.2. Methodological Contributions to Water-Resource Management Research

The innovative approach of bringing together and using SNA, the analysis of interviews, and ABM in this research has allowed for an investigation of the social dimensions involved in water-resource management at the catchment-scale. Through the mapping out and visualisation of the network stakeholders working in water-resource management in the Wear Catchment, it has assisted with the identification of which stakeholders are involved, and also those who are not largely involved, or indeed not involved at all in the current Wear Catchment-management system. By the mapping of the purposes of, reciprocation and strength of ties between stakeholders, it has allowed for detailed investigation and understanding of the ways of working of the stakeholders and their involvement relative to one another in the Wear Catchment. In doing so, this research has demonstrated the value of using a network approach to understanding and investigating the current state of water-resource management at the catchment-scale; and is a method that could be used to compare the involvement of stakeholders in other catchments, with that of the Wear, from across the UK, in the assessment of the state of the implementation of the CaBA.

Using ABM in this research has demonstrated the worth of the approach in being able to offer further analysis and investigation upon that of SNA, to investigate the relationships and interactions between stakeholders involved in water-resource management. ABM offers a novel way of being able to test possible future scenarios of changes, such as the decreasing of stakeholder resources, and the complexities associated with water-resource management. Rather than relying on imagination, modelling allows for the scenarios to be played out in a modelled system of the real-world.

8.4. Recommendations for Research and Practice

Based on the findings of this research, along with the challenges and lessons learnt throughout the research process, there are a number of recommendations that can be made for research and practice, which can be subsequently used in future research in the catchment-management system of the Wear Catchment, and beyond, in the UK more widely. Therefore, the purpose of this section is to highlight the lessons learnt from this research, and the research process, that may be relevant to consider in future research and practice, referring to the investigation and analysis of the current state of water-

resource management in the Wear Catchment, focusing on the interactions and roles of stakeholders. Recommendations are made in relation to the use of the network approach for the mapping out, visualisation and analysis of stakeholders involved in water-resource management at the catchment-scale; and the factors involved in the management of water resources including the enablers and barriers to the functionality of the management approach, and also the use of modelling to investigate further the linkages between stakeholders.

Firstly, this research has demonstrated the benefits of using a network mapping approach to understand the characteristics and components of the catchment-management system. By understanding the position, connections and roles of the stakeholders, the research findings can be used to make suggestions to the stakeholders regarding changes that could be made to the system, to enhance and improve interactions between them, and thus improving the efficiency and sustainability of the management of water resources.

Secondly this research has shown that by combining SNA with thematic analysis of interviews, adds an additional dimension and depth of detail; and through the subsequent combining with ABM, an investigatory dimension to the study can be added. The additional dimension in this research allowed for the testing of scenarios of change in the interactions of managing water resources of stakeholder organisations and the overarching Wear Catchment Partnership. Findings which can be subsequently provided to stakeholders and used as a discussion starter regarding future changes in the management of the system that could be made.

Thirdly, in the context of the Wear Catchment, stakeholders work together well in most cases, with reciprocated relationships involving data sharing, political support, problem-solving and decision-making interaction. Therefore, the Wear Catchment gives an example of good collaborative practice, with well-connected stakeholders, sharing experiences, expertise and knowledge with one another. However, despite now being in the eighth year of operation, there is still progress to make with the implementation of the CaBA in the Wear Catchment with opportunities for the involvement of community groups, as well as organisations including Sunderland City Council.

Fourthly within the network, trust is an essential element of the establishment and maintenance of relationships between stakeholders. In the Wear Catchment, the Wear Rivers Trust play a pivotal role at the centre of the network of the system, with links to a number of other voluntary sector organisations, as well as those in both the public and

private sectors. This is in addition to the Wear Rivers Trust facilitating the Wear Catchment Partnership. Along with trust within and between the stakeholder organisations, the knowledge, expertise and understanding of catchment-processes is key. To maintain good working practice and linkages between stakeholder organisations, individuals are key. Without individuals within the organisations the linkages between organisations would not be possible.

8.5. Future Research

Ultimately, the methods used in this research could be easily used in other catchments in the UK to analyse and investigate the current state of water-resource management, with respect to the CaBA. The CaBA is very much still evolving, with areas that can be improved. Therefore, by greater knowledge of the network of stakeholders and their working practices, including their roles and their interactions with one another in the management of water resources will be beneficial in taking steps forward in the future with the CaBA, informing policy as well as achieving the goals of the WFD, for example.

As this research only focused on the current state of water-resource management in the Wear Catchment, it would be useful to attempt to track changes through time, adding a temporal dimension to the analysis. A temporal dimension could be added through the repetition of the process of data collection via surveys of how changes and relationships between stakeholders change overtime, with follow-up interviews to explain why changes have occurred. By combining the analysis of temporal changes in the network of stakeholders through time with SNA, ABM could be used to run additional scenarios of change, comparing modelled future scenarios with actual changes in the network system.

Additionally, by the mapping out of the network of stakeholders across different catchments across the UK, spatial comparisons in the balance of stakeholders from the public, private and voluntary sectors could be made. Ways in which the CaBA is being implemented in other catchments could be used to inform changes in practice, such as what is working well or not so well.

In the ABM created in this research, enhancements could be made to allow for communication between stakeholders, rather than just the stakeholders and the Wear Catchment Partnership as a whole. Stakeholders could work together in acquiring data, creating new working relationships over the course of the model duration. Due to time constraints, both of the PhD research process, and time available for individuals from the

stakeholder organisations to participate, there was no direct involvement or input in the modelling process. The process of ABM could be enhanced through the greater involvement of stakeholders. Participatory modelling, involving stakeholders would be an interesting, and potentially beneficial addition in the creation of a model of the catchment-management system. Stakeholders could participate in informing the modelling process with the desires of what they would like to be modelled with reference to scenarios of change in the modelled network system.

Appendix A

Consent Form

Durham University

Analysis of the Current State of Collaborative Water-Resource Management in the UK Using Social Network Analysis and Agent-Based Modelling: a Case Study in the Wear Catchment

This form is to make sure that you have been given information about this project. It is to confirm that you know what the project is about and that you are happy to take part. Please tick the boxes you agree with below.

I know what the project is about. ☐

I know I don't have to answer all the questions I'm asked. ☐

I agree to the interview being recorded (if applicable). ☐

I agree that an anonymous record of my responses can be securely kept for future reference. ☐

Would you like to take part? Yes ☐ No ☐

Signed_____

Name_____

Date_____

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